SEPTEMBER 1961
VOLUME 1, NUMBER 9

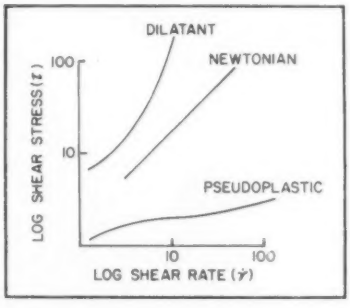
Materials Research & Standards

Bulletin of AMERICAN SOCIETY FOR TESTING MATERIALS

$$\eta = \frac{\tau}{\dot{\gamma}}$$

NEWTON AND THE NON-CONFORMIST FLUIDS

Newton's classical hypothesis, stated above, provides a basis for the study of viscous flow. However, many viscous fluids behave in a non-Newtonian manner. In polymer melts, for example, viscosity may vary with pressure and flow rate. These properties must be measured — with accuracy — in order that their behavior may be predicted in advance. Knowledge of flow behavior assists the researcher in studying molecular structure . . . helps the engineer in designing more efficient process equipment. Which is why we're using this space to tell you about the new Instron Capillary Rheometer, a valuable and versatile new tool for studying the behavior of polymer melts and other non-Newtonian fluids.



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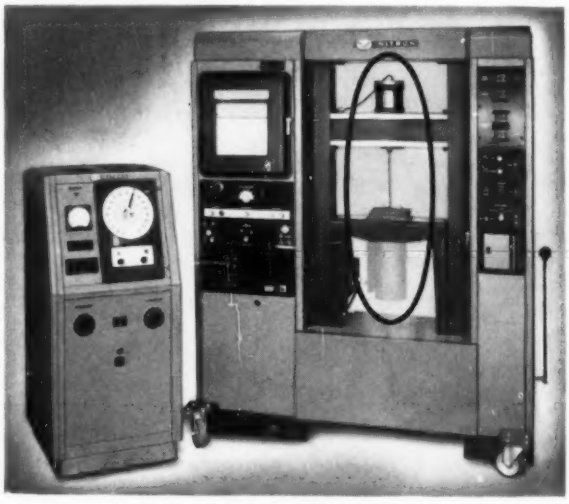

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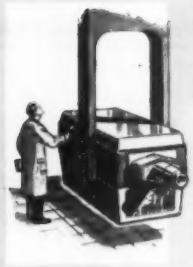

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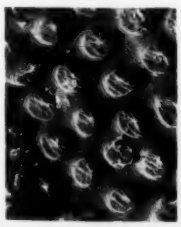

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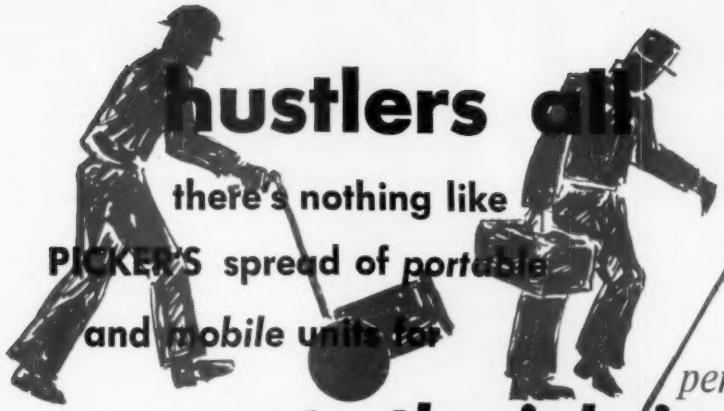

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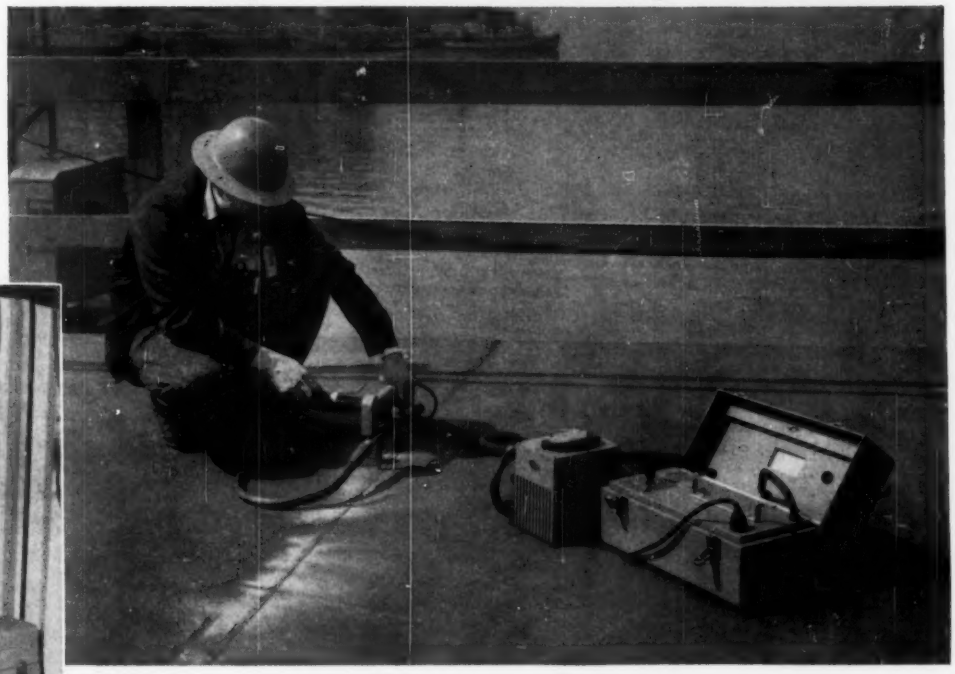

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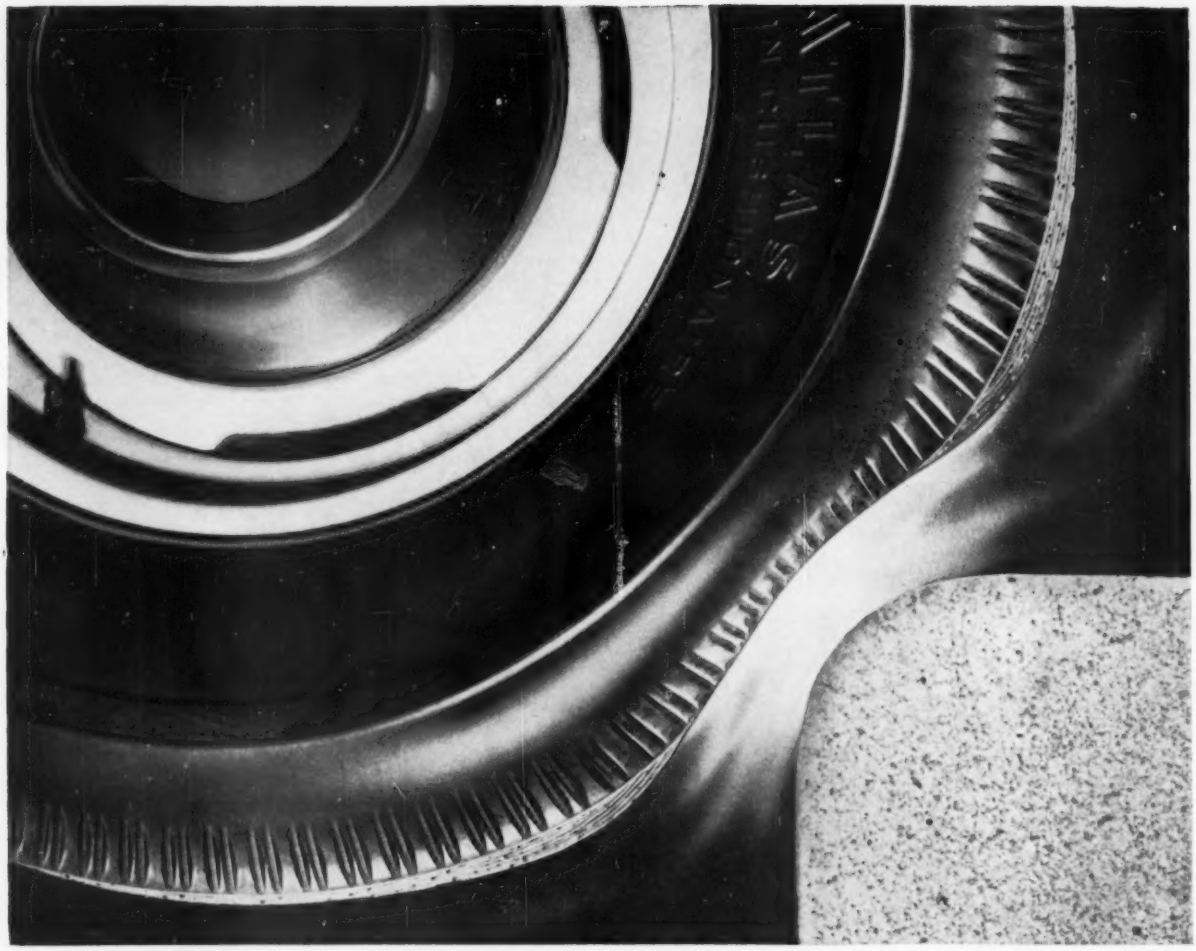

IMPACT!

New Plas-Tech High-Speed Universal Tester Gives

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THE PROBLEM Esso Research was concerned with simulating and measuring in the laboratory those high-speed forces that rubber tires are exposed to in service. Conventional slow-speed or "static" universal test equipment (e.g. capable of speeds up to 50 inches/minute) could not provide the answers.

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Materials
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Volume 1, Number 9, September, 1961

Ad Astra?

SOME MONTHS AGO, in the dim, distant, pre-Gagarin days, we made a brief comment here on the relative value of flights to the moon. The die is now cast, but we cannot resist a parting shot in the form of this three-way guest editorial:

"Major Gagarin's feat has caught the world's fancy, and we may as well face up to it. The question is, are we wise in choosing manned flight into space as the primary event in these scientific Olympic Games?

"I am not persuaded that this is the battleground of choice. I personally would much rather choose scientific issues which have more bearing on the world that is part of man's everyday environment and more bearing on man's welfare. . . . I suspect that most Americans would prefer to belong to the society which first gave the world a cure for cancer than to the society which put the first astronaut on Mars.

"But it is presumptuous for me to urge that we study biology on earth rather than biology in space. . . . What I am urging is that these choices have become matters of high national policy. . . . We should have extensive debate on these over-all questions of scientific choice; we should make a choice, explain it, and then have the courage to stick to a course arrived at rationally.

"In making our choices we should remember the experiences of other civilizations. Those cultures which have devoted too much of their talent to monuments which had nothing to do with the real issues of human well-being have usually fallen upon bad days: history tells us that the French Revolution was the bitter fruit of Versailles, and that the Roman Colosseum helped not at all in staving off the barbarians. So it is for us to learn well these lessons of history: we must not allow ourselves, by short-sighted seeking after fragile monuments of Big Science, to be diverted from our real purpose, which is the enriching and broadening of human life."

"Impact of Large-Scale Science on the United States," Alvin M. Weinberg, *Science*, Vol. 134, No. 3473, pp. 161-164, 21 July 1961.

"Now it is time for this nation to take a clearly leading role in space achievement which, in many ways, may hold the key to our future on earth.

"I believe that this nation should commit itself to achieving the goal, before this decade is out, of landing a man on the moon and returning him safely to earth. . . . No single space project in this period . . . will be so difficult or expensive to accomplish."

Message to Congress, John F. Kennedy, May 25, 1961.

I met a traveller from an antique land
Who said: "Two vast and trunkless legs of stone
Stand in the desert . . . Near them, on the sand,
Half sunk, a shattered visage lies, whose frown,
And wrinkled lip, and sneer of cold command,
Tell that its sculptor well those passions read
Which yet survive, stamped on these lifeless things,
The hand that mocked them, and the heart that fed.
And on the pedestal these words appear:
'My name is Ozymandias, king of kings:
Look on my works, ye Mighty, and despair!'
Nothing beside remains. Round the decay
Of that colossal wreck, boundless and bare
The lone and level sands stretch far away."

"Ozymandias," Percy Bysshe Shelley

A.Q.M.

Volume Changes in Concrete

BY MYRON A. SWAYZE

THE SHRINKAGE of concrete when exposed to drying and expansion when rewetted have long been the concern of engineers who deal with this material. In recent years we have had attempts by different means to decrease concrete shrinkage and cracking due to drying. One method, used in Europe, is to mix portland cement with reactive materials (such as aluminous cement) which cause an early expansion to counteract the later shrinkage of normal concrete as it dries. Another method considered here in recent years was to delete the SO_3 (sulfur-trioxide) limits in our cement specifications and substitute a requirement for "optimum SO_3 content," based on a test for residual soluble SO_3 in mortar after 24 hr of hydration, with proposed minimum and maximum limits on residual SO_3. This attempt failed because the test was not reproducible in different laboratories or from day to day in the same laboratory. What the obviously increased gypsum requirement would have done to the problem of false set in cements—already troublesome to many cement manufacturers—was a subject not considered by advocates of optimum SO_3.

Early in 1960 two more direct proposals were made to test cements in 1- by 1- by 10-in. bars made either from 1:2 standard sand mortar or neat paste and to place restrictive limits on the shrinkages that develop at very early ages. In the mortar test, proposed by a West Coast highway laboratory, the bars are removed from molds at 22 to 23½ hr, immersed in water until 24 hr old, then measured and resoaked for 2 days. Expansions are then measured, after which the specimens are exposed to drying in 50 ±4 per cent relative humidity (RH) for 4 days. Proposed limits are 0.01 per cent expansion in water and 0.04 per cent subsequent shrinkage in air after 4 days of drying.

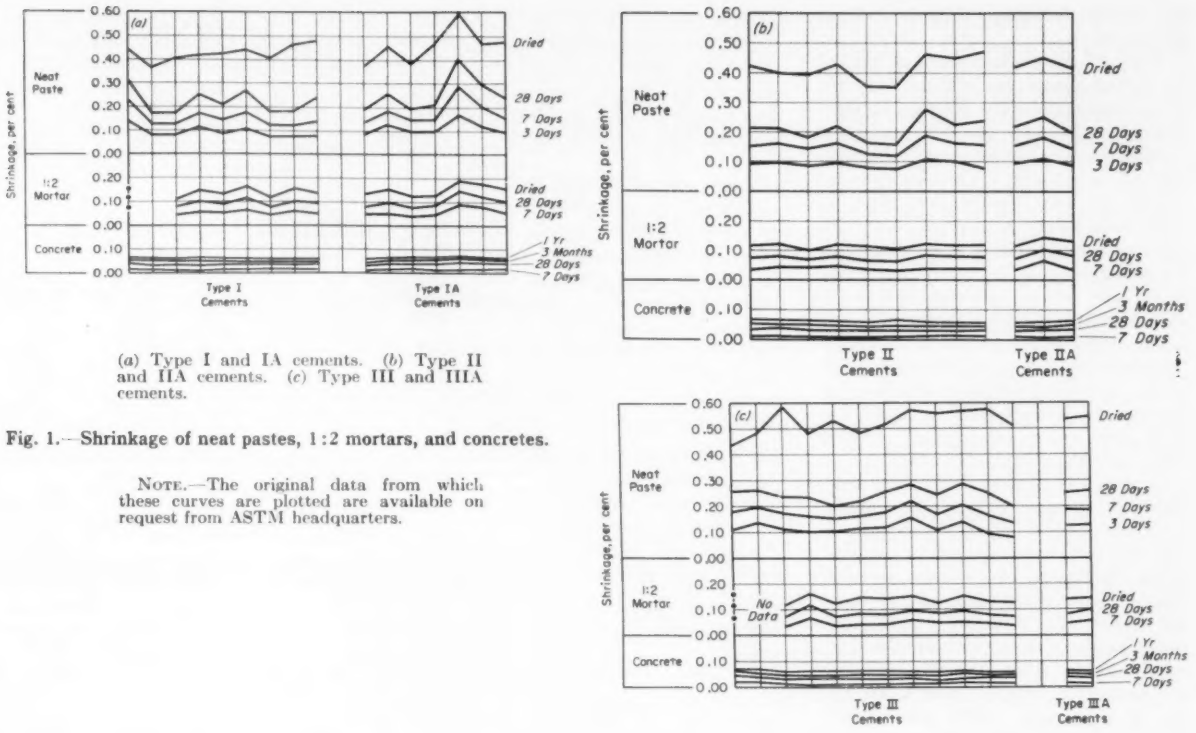
The second test on neat pastes proposed by a division laboratory of a Federal agency omits the water storage after removal of specimens from molds. Specimens are measured immediately after removal from molds at 24 hr, then stored in 50 per cent RH, with subsequent measurements daily until specimens are 7 days old. A tentative limit of 0.10 per cent shrinkage after 48 hr of drying (3-day specimen age) has been under consideration. A similar new proposal for a 0.09 per cent shrinkage limit on neat pastes after 48 hr of drying is being considered by the Advisory Group on Federal Specifications. All of these tests would reject many of the brands of cement made by our American cement industry. Of the various types of cement, type II has shown the best chance of acceptance and types I and III the least.

Besides these proposals to limit shrinkage of cements in neat pastes and relatively rich mortars by tests at very early ages, there are several other beliefs that have grown up regarding behavior of cements during drying of specimens. It has long been considered that increasing cement fineness, such as is done in making type III cement, leads to higher drying shrinkage in pastes, mortars, and concrete. It has also been assumed that when differences in shrinkage characteristics of a group of cements are found in neat pastes or rich mortar specimens, proportionate differences will be found in the shrinkages of concrete made with these products. It is further assumed that early tests on small neat paste or mortar specimens will somehow reflect the ultimate shrinkages to be found in larger concrete specimens. The Lone Star Cement Research Laboratory decided to check these theories.

At Lone Star's Hudson, N. Y., laboratory, concrete volume-change tests have been made on practically every batch of concrete mixed over a period of many years. The regular aggregates used are nonreactive siliceous sand and graded gravels, always from the same sources, usually combined to give a uniform grading from 0 to 1½ in. Mixes are normally designed to have cement contents of 3.6, 4.5, 6.0, 7.5, and 9.0 sacks per cu yd, with water additions to produce 2- and 6-in. slump. Three rounds of tests are made on each mix and slump. Two 3- by 3- by 10-in. volume-change specimens are cast from each batch of concrete. Concrete mix design is by the total fineness modulus method which includes the cement volume with an assumed fineness modulus of 0.00. Plain concretes are designed to have a total fineness modulus (TFM) of 4.85, and air-entrained concretes to have a TFM of 5.00. Gravel larger than 1¼ in. is discarded in casting volume-change specimens. Curing of these specimens is in plastic-covered molds for 24 hr. After initial measurements at 24 hr, specimens for expansion tests are stored under water. For shrinkage tests, the bars are cured in fog for 48 hr, then at 50 ±1 per cent RH up to the age of 1 yr. Past experience has shown that at 1 yr the dried specimens are at or very close to their ultimate shrinkage. Up to 1960 we have not made similar tests on mortars or neat cement specimens, owing to the tendency of some otherwise well-informed engineers to translate the higher shrinkages exhibited by such specimens into terms of contraction in inches per hundred feet of concrete pavement and to draw erroneous conclusions from such figures.

To check the volume-change behavior of cements in concrete against their volume changes in neat pastes and 1:2 mortars, a group of 56 cements of all types except type IV and V, on which a very comprehensive series of tests has been run, was selected for casting of neat paste and mortar specimens. The concrete tests on these cements were started in 1957 and have very recently been completed. Representative samples of each cement had been preserved in sealed metal cans and were used for the casting of the 1-in. neat and mortar bars. Three specimens were cast for each cement and type of mix. Curing treatment and later exposure of these specimens in general followed the procedures of ASTM Tentative Method of Test for Volume Change of Cement

M. A. SWAYZE, director of research, Lone Star Cement Corp., is a graduate of Case Institute of Technology. An outstanding authority in the field of cement, he has been concerned for many years with testing and research problems. He has been abroad on numerous occasions in the interest of cement technology, and was selected in 1945 to conduct a survey of the German cement industry at the end of World War II for the Foreign Economic Administration.



(*a*) Type I and IA cements. (*b*) Type II and IIA cements. (*c*) Type III and IIIA cements.

Fig. 1.—Shrinkage of neat pastes, 1:2 mortars, and concretes.

NOTE.—The original data from which these curves are plotted are available on request from ASTM headquarters.

Mortar and Concrete (C 157),[1] except where the method either contained inexplicit directions or recommended unacceptable practices, such as oiling of molds and use of paint on specimens. Our procedures for each type of specimen are given in the Appendix to this paper. These modifications of Method C 157 yielded very close agreement among individual specimens from the same lot. All specimens were measured to 0.0001 in. and volume changes recorded to 0.001 per cent.

The data here presented cover the 42 cements on which we have complete data for 1 yr on concrete volume changes. In the case of the data on concrete, each figure plotted is an average of tests on 18 specimens, each representing single concrete batches containing 4.5, 6.0, or 7.5 sacks of cement per cu yd and with slumps of 2 and 6 in. The corresponding data on neat pastes and 1:2 mortars are averages on three individual specimens. To shorten the time required for conclusions regarding these data, the neat paste and mortar specimens were subjected to drying in 50 per cent RH only until the age of 28 days. After this age, all specimens were dried in an oven at 105 C for 48 hr, returned to the 50 per cent R-H storage for 24 hr, with final measurements at 31 days after casting. All of these data for individual cements of each type are plotted in Fig. 1. The compound compositions, SO_3 in hydrated mortar at 24 hr, and Wagner fineness are shown in Table I. In all cases the volume-change test ages refer to the age of specimens after casting. All shrinkage data are related to the individual initial measurements after removal from molds rather than to those made after 48 hr of fog or water curing.

Figure 1 shows comparisons between the gradual shrinkage of the 3-in. concrete specimens up to their ultimate shrinkage at the age of 1 yr and the more rapid and larger early shrinkages of mortar and neat cememt specimens for the same cements. Figure 1(*a*), which covers type I and IA cements, presents several noteworthy points: First, the 3-in. concrete specimens developed about 20 per cent of their final shrinkage in 7 days, nearly 60 per cent in 28 days, and 80 per cent in 3 months. In contrast, the data on 1-in. neat cement specimens show they had lost only part of their evaporable water in 28 days; two days of oven drying increased shrinkages to such an extent that the 28-day values for storage at 50 per cent RH are only 50 to 55 per cent of the shrinkages after oven drying. The mortar specimens, being more permeable and having higher initial water content, showed 28-day values to be about 65 to 70 per cent of the oven-dried values. More significantly, while there is fairly good agreement between the two types of small specimens, they do not necessarily reflect the behavior of the cement in concrete. For example, the last three type I cements had the lowest 1-yr shrinkages in concrete for this group but displayed quite different results in their neat pastes and mortars.

Figure 1(*b*), covering type II and IIA cements, shows similar anomalies. The sixth type II cement is close to the maximum in ultimate concrete shrinkage, yet displays the lowest shrinkages in neat paste and mortar. The last three normal type II cements have minimum concrete shrinkages but give relatively high results in neat and mortar specimens.

Type III and IIIA cements (Fig. 1(*c*)) again present confusing results. Their shrinkage behavior in concrete almost exactly parallels the behavior of types I or II or their air-entraining counterparts. The notable differences in behavior of these finely ground cements from cements of normal fineness is their higher shrinkage at all ages in neat pastes, and in the relatively high amount of shrinkage left after 27 days in storage at 50 per cent RH, which was brought out by subsequent drying at 105 C. We attribute these differences largely to the higher amounts of water required by type III cement pastes and to slower losses of water from these pastes due to faster development of impermeability. The 1:2 mortars made with normal amounts of water were more permeable and did not display these differences. However, their shrinkages on individual cements were a poor index of what might be expected

[1] 1958 Book of ASTM Standards, Part 4, p. 720.

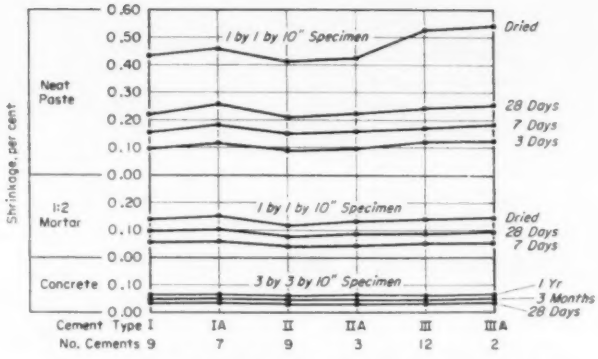
of ultimate shrinkages of these cements in concrete.

Figure 2 shows the effects of type of cement on shrinkages in the three kinds of specimens, using the averages for each cement type. In concrete, ultimate shrinkages were almost exactly the same for all six types. Development of shrinkage was slowest for type II cements and fastest for type I, although both reached exactly the same average level at the age of 1 yr. We recognize this slower rate of hydration and therefore shrinkage in type II cements by our lower strength requirements in ASTM specifications. Air entrainment evidently increased ultimate shrinkage in concrete by a mere 0.001 or 0.002 per cent, but had a considerably greater effect in neat pastes and mortars.

It should be obvious from these data that high fineness in type III cements does not cause higher shrinkages in concrete than will be found for cements of normal fineness, as has been assumed from tests made on neat paste or mortar specimens. Further, neither of these proposed tests can furnish any reliable index of how any given cement will perform in concrete, so far as shrinkage is concerned. Both tests badly overrate the assumed low ultimate shrinkage characteristics of type II cements in concrete, which assumption can be seen as contrary to fact. Further, no short-time test on neat pastes or 1:2 mortars at 3, 7, or even 28 days can hope to approximate the ultimate shrinkage of a cement in concrete, which is what we are interested in from a structural standpoint.

The principal part of our fallacious thinking on volume changes in any sort of test specimen springs from the false assumption that shrinkages are attributable purely to induced volume changes in the cement paste, due to loss of evaporable water from the specimen. This is far from the truth. As pointed out in an earlier paper,[2] there is another appreciable influence at work during cement hydration that should be termed autogenous volume change. As cement hydrates, the volume of the hydration products is always less than that of the unhydrated cement plus the volume of water with which it has combined. Coupled with this is another decrease in volume of that part of the mixing water which is adsorbed on the surface of the extremely fine gel structure. The combination of these two volume decreases is substantial, even at early ages. In terms of absolute volumes of cement involved, the per cent of water volume decreases due to chemical reaction and adsorption for normal and

[2] M. A. Swayze, "Early Concrete Volume Changes and Their Control," *ACI Journal*, Vol. 13, No. 5, p. 425, April, 1942.



NOTE.—The original data from which these curves are plotted are available on request from ASTM headquarters.

Fig. 2.—Effect of type of cement on shrinkage of neat pastes, 1:2 mortars, and concrete in 50 per cent relative humidity.

TABLE I.—COMPOSITION OF CEMENTS AND MISCELLANEOUS DATA: VOLUME-CHANGE SERIES.

Sample Number	Plant	Composition, per cent								SO_3 hydrated mortar, g	Fineness, Wagner
		C_3S	C_2S	C_3A	C_4AF	MgO	Na_2O	K_2O	SO_3		
TYPE I CEMENTS											
2737	D	41.0	28.4	13.5	7.7	3.6	0.32	0.82	2.16	0.005	1880
2753	B	47.6	28.9	9.7	6.6	0.7	0.13	0.31	2.22	0.00	1780
2760	I	43.6	30.4	9.9	9.8	1.3	0.08	0.22	2.05	0.01	1810
2801	F	49.7	26.9	9.5	7.5	1.7	0.10	0.72	1.97	0.015	1870
3048	L	55.2	18.7	8.7	10.5	1.1	0.45	0.15	2.31	0.01	1990
3066	D	46.8	24.2	12.6	6.7	3.3	0.23	0.70	2.54	0.01	1810
3076	I	42.8	32.3	12.5	5.8	1.0	0.11	0.22	2.45	0.025	1450
3114	K	48.6	24.5	10.2	9.6	0.9	0.11	0.27	2.36	0.03	1840
3098	M	59.8	18.9	6.8	9.1	1.3	0.25	0.44	1.74	0.015	1800
TYPE IA CEMENTS											
2798	H	51.8	16.8	12.5	11.1	0.9	0.10	0.39	2.01	0.02	1850
2828	F	44.2	29.6	10.3	7.1	1.5	0.12	0.69	2.49	0.02	1760
2833	B	49.7	24.9	11.9	7.2	0.9	0.10	0.45	2.14	0.02	1710
2838	L	59.7	13.1	8.8	10.3	1.2	0.50	0.14	2.39	0.01	2190
2839	D	41.4	29.8	13.5	6.1	3.8	0.27	0.77	1.97	0.04	1680
3073	D	47.5	23.5	12.8	7.0	3.4	0.24	0.73	2.45	0.02	1840
3113	M	59.8	18.3	7.5	8.4	0.6	0.26	0.44	1.85	0.01	1900
TYPE II CEMENTS											
2712	A	46.4	29.4	5.3	12.6	1.4	0.21	0.48	2.04	0.02	1960
2742	D	38.5	34.4	7.2	11.1	3.5	0.20	0.63	2.01	0.00	2050
2754	E	41.9	33.0	4.4	14.9	0.9	0.56	0.26	1.79	0.005	1860
2767	G	46.8	29.9	3.8	11.8	3.0	0.14	0.54	1.68	0.000	1930
2810	I	40.3	36.7	5.1	12.9	1.0	0.09	0.22	1.80	0.01	2050
2812	H	38.6	34.9	5.3	15.2	0.9	0.08	0.38	2.07	0.01	2120
2994	D	33.4	38.2	7.5	12.5	3.4	0.17	0.64	2.22	0.05	1840
3020	J	49.2	28.7	6.9	8.8	1.0	0.55	0.23	2.02	0.02	1830
3037	M	40.9	37.0	7.7	9.2	1.2	0.17	0.52	1.88	0.01	1910
TYPE IIA CEMENTS											
2713	A	41.9	34.7	6.0	11.2	1.4	0.22	0.48	1.90	0.01	1930
2778	G	48.4	27.7	5.7	11.0	3.0	0.16	0.64	1.63	0.00	1900
2832	E	43.1	32.1	4.2	14.1	0.8	0.66	0.23	1.76	0.02	1940
TYPE III CEMENTS											
2738	D	44.5	24.0	13.5	6.4	3.7	0.27	0.72	2.81	0.005	2670
2750	F	60.9	15.1	9.7	6.2	1.4	0.10	0.72	2.62	0.01	2640
2762	M	55.4	23.3	1.4[a]	12.5	0.7	0.14	0.16	2.62	0.055	2750
2788	D	48.8	20.9	13.3	6.2	3.7	0.30	0.72	2.71	0.005	2710
2782	K	60.7	11.1	10.7	9.7	0.9	0.12	0.18	2.93	0.000	2620
2794	L	59.4	11.2	10.0	9.4	1.2	0.59	0.06	2.88	0.025	2960
2813	A	61.0	14.2	5.2	12.4	1.3	0.17	0.37	2.39	0.03	2760
2817	N	58.6	21.7	5.7	5.4	1.9	0.06	0.05	2.57	0.035	2660
2990	M	66.1	14.5	2.4[a]	10.9	0.8	0.04	0.10	2.41	0.135	2980
3075	G	57.3	18.2	9.6	5.4	3.0	0.15	0.22	2.47	0.06	2700
3078	C	71.1	7.9	0.2[a]	13.0	1.8	0.11	0.13	2.70	0.095	2790
3107	I	71.0	2.3	5.7	13.6	1.4	0.09	0.24	2.42	0.01	2650
TYPE IIIA CEMENTS											
2836	A	66.1	8.3	3.3	13.9	1.2	0.17	0.37	2.40	0.06	2780
2843	F	62.8	13.0	9.1	7.5	1.7	0.12	0.54	2.68	0.03	2750

[a] C_2F

high early strength cements is as shown in Table II. These data are based on tests with two type I and type II, and four type III cements.

TABLE II.—AUTOGENOUS VOLUME CHANGES IN PASTES.

Age	Water-Volume Decrease, per cent		Equivalent Per Cent Water by Weight	
	Types I, II	Type III	Types I, II	Type III
6 hr.....	1.12	2.00	0.35	0.64
14 hr.....	3.59	5.56	1.13	1.78
24 hr.....	5.18	7.73	1.64	2.48
2 days...	7.42	10.12	2.35	3.24
7 days...	11.44	13.21	3.62	4.28
28 days...	13.57	15.22	4.31	4.88

The decrease in water volume due to combination with the cement and adsorption is just as effective in producing shrinkage in a dense cement paste as is the loss of an equal volume of water by evaporation. Since only the volume decreases which take place after the initial measurements at 24 hr are effective in producing measurable shrinkage, it is interesting to note that the autogenous volume changes through 28 days amount of 2.67 per cent for type I and II cements, and 2.40 per cent for type III cements.

If we relate these autogenous shrinkages of cement paste to the three varieties of test specimens, it should be easily apparent that they have most effect on neat pastes, since these contain only 24 to 26 per cent of added water to begin with. The 1:2 mortars are less affected by autogenous shrinkage with their 37 to 39 per cent added water. Concretes are least affected. With their larger amounts of mixing water, the volume decreases due to autogenous shrinkage become insignificant.

It therefore seems inconsistent to rely on the behavior of either neat pastes or rich mortars to predict the ultimate shrinkage of concretes, especially if the tests are concluded at early ages. The comparative data presented here appear entirely too erratic for any such reliance.

One point that has a general bearing on concrete shrinkage is C_3S content of cement, although this cannot be taken completely for granted. Early Bureau of Reclamation data on the low-C_3S cements used in Hoover Dam showed these cements had high concrete shrinkages in comparison with those of normal composition. The present data reveal these same trends, although exceptions are almost as numerous as those following the trend.

Conclusions

The general conclusion to be based on the outcome of the tests presented here is that if information is desired on the shrinkage of cement in concrete, the test specimens should be of concrete. Either neat paste or 1:2 mortar results are entirely too erratic for reliance.

ASTM Tentative Method C 157 covering volume-change tests is badly in need of revision to give more explicit procedures and to eliminate inaccurate procedures in studies of volume change

APPENDIX

ASTM Tentative Method of Test for Volume Change of Cement Mortar and Concrete (C 157) includes a number of inexact directions for conducting volume-change tests, and other procedures which are conducive to variable results between laboratories, or within the same laboratory during day-to-day testing. In order to obtain uniform results on companion specimens or between identical specimens made on different days, the following points must be strictly observed.

Recommendations

1. Presence of oil or grease on specimens will retard evaporation of water. Molds must therefore never be coated with grease or oil, nor should specimens be marked with an oil-base paint or wax crayon. Where specimens are fragile at the age of 24 hr, molds should be lined with thin rubber or waterproof plastic, and this stripped completely from specimens after their removal from the molds. Neat specimens can be removed from dry molds without damage if the molds are thoroughly clean. Marking of specimens should be with soft graphite pencil or by tags.

2. Curing of specimens in molds for 24 hr under uniform conditions is highly important. During this period specimens must neither gain nor lose water if uniform tests are to be obtained. Even the best moist cabinets have variable humidity during periods when specimens are being put in or removed. After specimens are cast, the molds should therefore be enclosed in waterproof plastic or other impermeable material until specimens are removed. If appreciable time elapses between removal and the initial measurement, the specimens should be wrapped in waterproof plastic until measured. Avoid any wetting of specimens during this period.

3. All measurements should be on 10-in. specimens to the closest 0.0001 in. and recorded to the nearest 0.001 per cent. Two good operators can check each other this closely if specimens are rotated in the gaging apparatus and average indicated lengths are observed. For reporting, data should be averaged to the nearest 0.001 per cent and so reported.

4. The maximum size of concrete specimen that can attain ultimate shrinkage within 1 yr is 3 by 3 by 10 in. The 4 by 4 by 10-in. bars recommended by Method C 157 should still have some residual shrinkage at that time.

General directions governing all volume change tests in the Lone Star Cement Corp. Research Laboratory included the above points, and in addition the injunction that temperatures of cements, aggregates, work room, moist cabinet, fog room, and mixing water must all be maintained at 73 ±3 F. Specific directions for making and testing each variety of specimen were as follows:

Neat Paste Tests.—Mix 500 g cement with the amount of water required for normal consistency. Mold three 1 by 1 by 10-in. bars for each cement and finish as described in Method C 151, except that molds must not be oiled or greased. After trowel finishing of specimens, immediately cover the specimens and molds with Saran or an equally impervious plastic covering and store in the moist cabinet for 23¾ to 24 hr. Then remove the specimens from the molds and make initial length measurements immediately after removal. If more than three specimens are removed at once, wrap the excess specimens in Saran until just before measurement. Mark specimens with a soft graphite pencil rather than with wax crayons or paint.

Following the initial measurements, transfer the specimens to the constant 50 per cent humidity room and remeasure there at ages of 48 and 72 hr, and 7 and 28 days after casting. After the 28-day measurements, place the specimens in the drying oven at 105 C for 48 hr. Then transfer the dried specimens to the constant-humidity room for an additional 24 hr, then measure for final shrinkage. During all drying storage, individual specimens shall be laid on round bar racks and separated from each other by at least ½ in. to ensure uniform drying conditions.

1:2 Graded Ottawa Mortar Tests.—Molds shall be free from oil and grease and have their interior surfaces covered with Permacel electrical resistant tape or equal to prevent adherence of specimens to mold. Mix 500 g cement, 1000 g standard graded Ottawa sand, and sufficient water in the Hobart mixer to yield a flow in the range of 105 to 115. Fill the molds in two layers, compacting each layer with the ½ by 1-in. tamper. Work the mortar into the ends of molds around the reference pins to secure close contact. After compacting the top layer, cut off the mortar flush with the top of the molds and smooth the surface with a few strokes of the trowel. Mold three specimens for each cement.

After finishing of specimens, cover immediately with Saran and store in the moist cabinet for 23¾ to 24 hr. Follow the same procedure on immediate initial measurements as under treatment of neat cement specimens. Mark with a soft graphite pencil.

Immediately after making initial measurements, submerge specimens in 73-F water storage for a period of 48 hr. After this storage, remeasure the specimens for length while still wet, then wipe off excess

moisture and place in the 50 per cent constant-humidity storage. Remeasure the specimens at ages of 7 and 28 days after casting. Following the 28-day measurements, subject the specimens to 48 hr of drying at 105 C and an additional 24 hr at 50 per cent RH before final measurements at 31 days. Observe the same separation of specimens in drying storage as for neat bars.

Concrete Volume-Change Tests.—Mold two 3 by 3 by 10-in. bars from each $\frac{1}{10}$ cu yd batch of concrete. For 1½-in. maximum size of aggregate, discard the occasional pieces of gravel larger than 1½-in. Consolidate by rodding each of two layers thoroughly, with spading of sides and ends with a plasterer's trowel, working around reference pins at both ends carefully to ensure good contact. Molds should be prelined with thin rubber sheeting or plastic. Internal vibration should be used for mixes of 7.5 sacks per cu yd and 2-in. slump and mixes of 9.0 sacks for both 2- and 6-in. slump. After consolidation of the concrete, strike off excess concrete flush with the mold, finish surface with a few strokes of the trowel, and immediately cover with either waterproof plastic or an impervious wax paper. Place wet burlap over this cover and store on the laboratory table for 23¾ to 24 hr. Then remove the bars from the molds and make initial measurements immediately. Following these measurements, submerge one bar in water and place the other bar in the fog room. Remeasure both bars at the age of 72 hr. The expansion bar shall then be returned to water storage for subsequent measurements at ages of 7, 28, 91, and 365 days, all in a wet condition. Shrinkage bars shall be transferred to storage at 50 per cent RH after wiping off excess water. Bars shall be laid on round steel bar racks, with separations of 1 in. between specimens to ensure uniform drying conditions. Remeasure at ages of 7, 28, 91, and 365 days after casting.

DISCUSSION

MR. BAILEY TREMPER.[1]—The author has reached unfavorable conclusions with respect to the significance of drying shrinkage tests of small prisms of neat cement and 1:2 Ottawa sand mortar as indicators of the drying shrinkage of portland cement in concrete.

It is noteworthy that ASTM Committee C-1 on Cement recently has approved Proposed Specifications for Processing Additions for Use in the Manufacture of Portland Cement.[2] These specifications provide for the determination of the effect of additions on drying shrinkage by means of a test performed on mortar specimens. It appears, therefore, that Committee C-1, as a whole, does not share the view of the author.

The following discussion is devoted solely to the use of mortar specimens as a measure of the performance of portlant cement in concrete that is subjected to drying in outside exposure. It is not intended to imply that neat paste specimens are necessarily inferior, but rather that the writer lacks extensive experience with such tests.

The California Division of Highways has for several years made tests of portland cements in 1:2 graded Ottawa sand mortar by a standardized procedure in accordance with Test method No. Calif. 527-A, which is available to interested investigators. Both the repeatability and the reproducibility of the test, when performed in accordance with this method, have been established by carefully controlled procedures.

The data presented by the author include test results by a modification of ASTM method C 157, which is similar to Method 527-A but which departs therefrom in certain details. For the most part, the writer's investigations indicate that the author's modifications of the test method make no material difference in the observed results. On the other hand, the author's reported values are the average of only three specimens for each cement tested. Method 527-A requires that four specimens be tested, and it provides for the rejection of specimens that do not meet specified criteria for uniformity. There is no evidence in the paper that the author has applied such criteria before computing average results. There is no evidence that the author has made replicate tests to establish the repeatability of his test procedure. This subject is discussed because of its important bearing on correlation data that the writer will develop later.

It is the primary purpose of this discussion to question the author's philosophy as to the drying period of mortar or concrete test specimens that best provides an index of the performance of cement in concrete subjected to exterior exposure. It will be shown that the author's use of his data is unrealistic and that when the data are properly evaluated they show, in fact, a high degree of correlation between the drying shrinkage of mortar bars and concrete test specimens. It will be shown that concrete pavements and structures that are exposed out-of-doors in the continental United States do not reach a state of dryness comparable to that of laboratory specimens that are dried at 73 F and 50 per cent RH for more than short periods of time.

The ACI Manual of Concrete Inspection[3] states: "After concrete has dried to constant water content at one atmospheric condition, a drop in humidity will cause it to lose water or an increase will cause it to gain; hardened cement paste is hygroscopic. The paste and the concrete of which it is a part, shrink or swell with each such change in water content." Powers and Brownyard[4] report that the rate at which hardened cement paste loses water is extremely slow. The temperature and relative humidity of the atmosphere surrounding exterior concrete varies from hour to hour, from day to day, and from season to season. Concrete exposed to such an environment is subjected to influences tending to cause it to lose or take on water continuously, but, since the paste responds slowly to short-time changes, it must reach an equilibrium condition which depends on the prevailing or average temperature and relative humidity of the atmosphere.

A review of weather bureau records for the continental United States shows that only in a few southern states does the mean annual temperature exceed 70 F. Of approximately 300 weather bureau stations, only 21 show mean annual temperatures above 70 F. Of the latter, the prevailing relative humidity is well above 60 per cent, except in Arizona. Relative humidities at 7 a.m. characteristically are above 70 per cent.

Weather records, therefore, indicate that the probability of exterior concrete attaining a relative humidity as low as as 50 per cent is exceedingly remote. Confirmation of this statement has been obtained by direct tests under a variety of exposure conditions in California. Tests were made by drilling or forming a hole about 1 in. in diameter to various depths. The hole was lined with metal tubing which extended to within about 1 in. of the bottom of the hole and which was cemented in place with epoxy adhesive. The outlet of the tubing was closed with a screw cap. After a period of time, the humidity of the air within the enclosure reached equilibrium with the surrounding concrete. At appropriate intervals, the screw cap was removed and a humidity sensing element was inserted. The leads of the sensing element passed through a metal screw cap which replaced the original cap. Readings of relative humidity were made until a constant value was obtained. Usually this required about 1 hr. The sensing elements were calibrated fre-

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[1] Supervising Materials and Research Engineer, California Department of Public Works, Division of Highways, Sacramento, Calif.

[2] 1961 Preprint Report of Committee C-1 on Cement, Am. Soc. Testing Mats., p. 8.

[3] *ACI Manual of Concrete Inspection*, American Concrete Inst., Third Edition, p. 25 (1955).

[4] T. C. Powers and T. L. Brownyard, "Studies of the Physical Properties of Hardened Cement Paste," *Proceedings*, American Concrete Inst., Vol. 43 (1947); also *Bulletin 22*, Research and Development Laboratories, Portland Cement Assn., Skokie, Ill.

quently against saturated salt solutions which produced known values of relative humidity in the confined space above them.

Relative humidities measured within pavement slabs generally have been well above 80 per cent. A few observed values that were somewhat lower are not believed to be reliable. The high humidity within pavement slabs in contact with the ground may be explained by the transpiration of moisture from the subgrade.

Attempts have been made to explain the occurrence of transverse cracks that have developed in pavements after many years of service on the basis of long-time drying shrinkage. High measured relative humidities provide strong evidence that pavements do not continue to dry over long periods of time and, hence, do not continue to shrink.

Nonreinforced pavement slabs constructed in Missouri,[5] in August, 1956, developed no greater total drying shrinkage when measured in the late summer of 1958 than was measured in September, 1956.

In Washington, D. C., a pavement slab placed in September, 1930, reached its minimum length, as a result of moisture changes only, 2 yr later.[6] At this time, the length was only slightly less than the minimum reached in 1931. Measurements were continued to the age of 5 yr. During this period, the minimum seasonal length was always greater than that in 1932. The greatest winter-to-summer drying shrinkage also occurred during the second year.

The delayed development of cracks, or their progressive widening, can be explained in a more rational manner on the basis of thermal changes. Compressible material in expansion joints provides relief for compressive stresses due to temperature rise causing the slabs to elongate. Upon cooling, subgrade friction induces tensile stresses which can exceed the strength of the slab and produce a crack. Intrusion of foreign material into cracks causes progressive opening as a result of thermal cycling. Recognition of this behavior has led the majority of state highway departments to eliminate expansion joints in nonreinforced pavements.

The relative humidity within concrete bridge structures of varying age has been measured at eight locations within California at points carefully selected to represent the range in weather conditions and elevations within the state. Holes for this purpose were drilled to depths of 3 and 5 in. during July, 1960, in each of the selected structures. When measured during late August and early September, 1960, after a prolonged dry season, relative humidities were found to be as shown in Table III. At only two of the eight locations were relative humidities less than 60 per cent, observed at a depth of 2 to 3 in. from the surface. Both locations were in desert areas. At a depth of 4 to 5 in., the lowest measured relative humidity was 60 per cent, in a desert area at an elevation of 4000 ft.

TABLE III.—RELATIVE HUMIDITY IN CONCRETE OF EXISTING BRIDGES IN CALIFORNIA AS MEASURED IN AUG. AND SEPT., 1960.

Location	Elevation, ft.	Date Built	Relative Humidity at Depth Shown, per cent	
			2 to 3 in.	4 to 5 in.
No. 1. Mojave Desert near Victorville	3000	1958	66	74
No. 2. Southern coast near San Diego	10	1956	80	80
No. 3. Central coast near Santa Cruz	10	1947	78	79
No. 4. Northern coast near Eureka	10	1929	84	85
No. 5. Central Valley near Sacramento	25	1959	74	78
No. 6. Sierra Nevada Range near Kingvale	6000	1959	70	77
No. 7. East of Sierra Nevada Range near Bishop	4400	1949	<50	60
No. 8. Imperial Valley near Salton Sea	−200	1950	58	67

Table IV gives periodic measurements at a location near Sacramento. Gradual lowering of relative humidity occurred during late summer and fall, a period without rainfall. Since the beginning of the rainy season and higher atmospheric humidity on Nov. 3, 1960, the trend has reversed and humidities within the concrete have risen. It would appear to be a reasonable expectation that similar cycles will be repeated annually with little change in the relative humidity reached at the end of the dry season.

The average relative humidity of the eight structures listed in Table III is is 72 per cent. A value of 70 per cent appears to be a good estimate for the end of the dry season. A comparison of weather records indicates that California weather on a state-wide basis embraces the typical range of the greater part of the continental United States. The use of 70 per cent as an estimate of the lowest relative humidity in exterior structures, therefore, appears to be realistic. Laboratory tests for drying shrinkage, therefore, should be discontinued after specimens have lost an amount of water that reduces the relative humidity to this condition.

Humidity readings at the center of a 3 by 3 by 11¼-in. concrete bar exposed to drying at 73 F and 50 per cent RH indicated that the concrete reached a relative humidity of 70 per cent after about 50 days. This indicates the appropriate maximum time of drying of such specimens under these conditions. It will be shown that a shorter drying period also yields similar relationships between different concretes.

The relative humidity within model beams, 14 by 20 by 48 in. in size, exposed outdoors at Sacramento, is shown in Table V. It is evident that rainfall and fog, accompanied by higher atmospheric humidity, was causing the concrete to take on, rather than lose, moisture after 84 days of exposure. These measurements were made in connection with a study of drying shrinkage of specimens of varying size that were exposed outdoors and also in the laboratory at 73 F and 50 per cent RH. The specimens were cast late in July, 1960. The concrete contained 6 sacks of cement per cu yd, 1½-in. maximum size aggregate, and water to give a slump of 3½ in. Concrete was mixed in the laboratory. Two types of concrete were used. One contained a lignin-base, water-reducing admixture in the proportions of ¼ lb per sack of cement. The other concrete contained no ad-

TABLE IV.—RELATIVE HUMIDITY IN CONCRETE OF EXISTING BRIDGE NEAR SACRAMENTO, CALIF. (LOCATION NO. 5 IN TABLE III).

Date of Measurement	Relative Humidity at Depth Shown, per cent	
	2 to 3 in.	4 to 5 in.
July 22, 1960	77	81
Sept. 12, 1960	74	78
Sept. 26, 1960	73	76
Oct. 21, 1960	68	72
Nov. 4, 1960	68	73
Jan. 3, 1961	78	75

NOTE.—No rainfall between May 24 and Nov. 2. 0.4 in. rain on Nov. 3. Total rain May 24, 1960, to Jan. 3, 1961, was 5 in.

TABLE V.—RELATIVE HUMIDITY IN 14- BY 20- BY 48-IN. CONCRETE BEAMS EXPOSED OUTDOORS AT SACRAMENTO, CALIF., SINCE EARLY AUG., 1960.

Period of Exposure, days	Relative Humidity at Depths Shown, per cent					
	Concrete Without Admixture			Concrete Containing Water-Reducing Agent		
	3 in.	5 in.	7 in.	3 in.	5 in.	7 in.
0	98	98	94	95	95	88
28	92	93	82	91	92	84
56	89	91	81	86	90	82
84	88	90	80	85	88	81
112	86	89	78	84	88	79
140	89	95	79	87	92	82

NOTE.—No rainfall during first 84 days of exposure. Rainfall since then, up to 140 days, has been 5 in.

[5] J. L. Best, W. D. Stites, W. F. Alch, and E. W. Carlton, "Length Changes in Prestressed Concrete Slabs," Missouri State Highway Commission, August, 1960.

[6] L. W. Teller and Earl C. Sutherland, "The Structural Design of Concrete Pavements, Part 2," *Public Roads*, Vol. 16, No. 9, November, 1935.

mixture. The number of specimens cast from each of these concretes were:

Size, in.	Number of Specimens
14 by 20 by 48.....	1, concrete as mixed
4 by 5 by 18.....	6, concrete as mixed
3 by 3 by 11¼.....	10, concrete wet-sieved through ¾-in.
1 by 1 by 11¼.....	10, concrete wet-sieved through No. 4

The largest specimens, or model beams, were intended to represent near job-size structural members. The ends were painted to retard moisture loss from these surfaces and thus more nearly represent a long beam. After moist curing in the laboratory for 7 days, the large model beams and half of the smaller bars were exposed out of doors. The remainder of the small specimens were exposed to controlled drying in the laboratory at 73 F and 50 per cent RH. The large beams were supported at the quarter points on pedestals above a concrete slab. Roller and ball bearings afforded free movement. Smaller specimens were supported on bars. All outside specimens were covered with removable gable roofs to prevent direct access of rain.

The results of measurement of shrinkage are shown in Fig. 3.

During the first 56 days of exposure, there was no rainfall, and shrinkage was proportional to the logarithm of time. Subsequently, there was considerable rainfall, fog, and rising atmospheric humidity. The effect was to cause a lengthening of the specimens. A comparison of drying shrinkage between the smaller specimens exposed outside and in the laboratory is shown in Fig. 4.

Length measurements of the smaller specimens were between gage studs at the ends. Length changes of the large beams were indicated by Carlson strain gages at the center of the section and between points in gage studs, in four rows at 10-in. centers, of each side face. Thirty-two measurements were used to determine length changes near the surface.

The effect of temperature changes on observed measurements for shrinkage were eliminated for exposure periods greater than 28 days by bringing all specimens to the laboratory for 24 hr or until embedded thermocouples showed that the temperature was 72 to 73 F, which was the temperature at which orginal measurements were made.

The curves of Fig. 3 display a number of points of interest. The relationship between surface-volume ratio and shrinkage was approximately linear, with a small break caused by wet sieving the concrete used in the two smaller sizes of specimens. The admixture consistently increased drying shrinkage. Drying shrinkage increased in proportion to the logarithm of time.

A study of the test data indicates that equal amounts of shrinkage are developed among laboratory test specimens when dried for the periods indicated below:

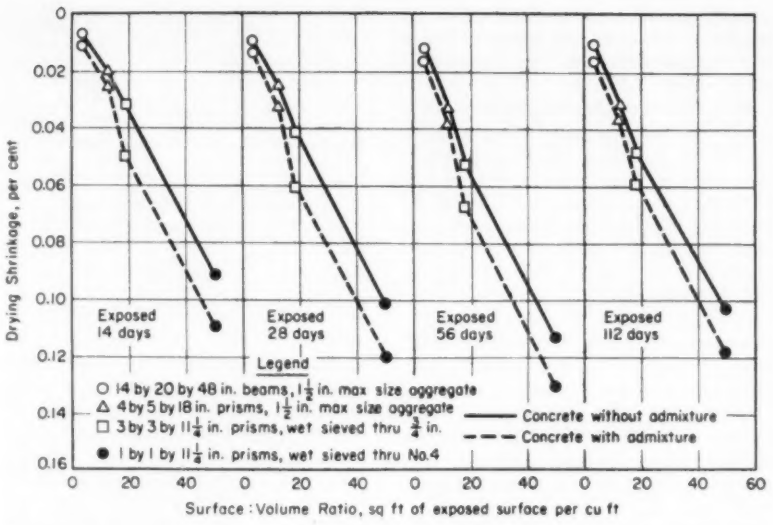

Fig. 3.—Relationship between drying shrinkage and surface-volume ratio. Specimens exposed outdoors.

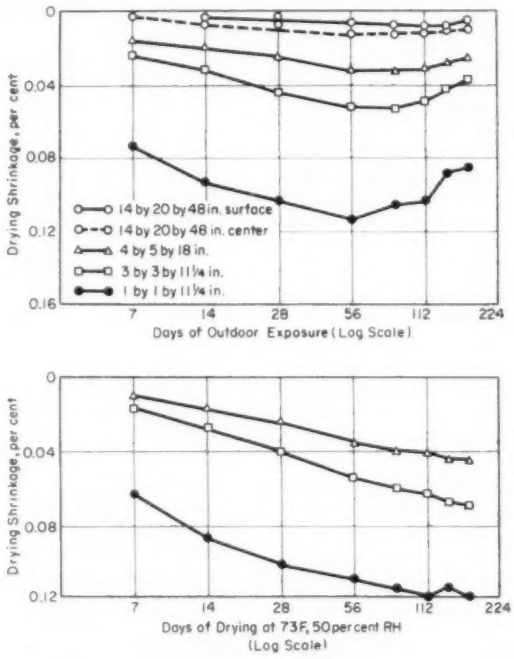

Fig. 4.—Drying shrinkage related to size of specimen and condition of exposure. Concrete without admixtures.

Section, in.	Days
1 by 1.....	4
3 by 3.....	14
4 by 5.....	28

It is also indicated that test drying for these periods will develop an amount of shrinkage that is fully as great as that normally to be expected in exterior concrete.

The data show that the relative increase in drying shrinkage caused by the use of the water-reducing agent is as follows:

Size, in.	Dried, days	Increase, per cent
14 by 20 by 48	56	38
4 by 5 by 18	28	32
3 by 3 by 11¼....	14	41
1 by 1 by 11¼....	7	45

It is reasonable to expect, therefore, that different cements will show propor-

tionate values of drying shrinkage in 1-in. mortar bars and 3-in. concrete bars if the times of drying are suitably selected.

The advantages of using relatively short drying periods are the greater utility for control purposes and avoidance of the complicating, and possibly unequal, effects of carbonation of specimens of different sizes.

The above unavoidably long preamble has been necessary to establish the basis that the writer believes to be proper for evaluating the author's data on mortars in terms of his concrete tests. The comparison is best expressed as the shrinkage of one cement in terms of another. An example is afforded by the author's data for cements representing high and low shrinkage in the concrete specimens giving the length referred to that at the end of the 3-day moist-curing period, as set forth in Table VI.

It will be noted the difference in magnitude of drying shrinkage of the two cements in concrete specimens is greatest after 25 days of drying and decreases considerably at later periods. On a relative basis, the increase in shrinkage produced by cement 2738 is about the same in mortar dried for 4 days as in concrete dried for about 14 days.

Since the data for these two cements indicate that significant values of drying shrinkage are obtained from mortar dried for 4 days, the data have been examined to determine how closely the relationship holds for the group of 40 cements as a whole.

The data for concrete are given at test ages of 7 and 28 days, representing 4 and 25 days of drying. It would be desirable to interpolate between these values to estimate shrinkage after 14 days of drying. But since the values, although reported to the third decimal, contain only two significant places, such interpolation, if carried only to two significant places, would not be of great value. In lieu of this procedure, the mean of shrinkage after 4 and 25 days of drying has been computed. In view of the relationship of shrinkage to the logarithm of time, the computed value represents the shrinkage developed at approximately 10 days. The amount of shrinkage has been computed with respect to the length at the end of the moist curing period, 3 days, rather than at 1 day as reported by the author. This value, in the opinion of the writer, has more merit in determining performance in service. Mean values have been computed to the nearest 0.0005 percentage point to give some measure of approach to three significant figures. Values of shrinkage of the mortar bars as reported at the age of 7 days, or 4 days of drying, are used. They are also referenced to the length after 3 days of moist curing. These values are reported to two significant places also, but

TABLE VI.—RELATIVE DRYING SHRINKAGE OF TWO CEMENTS, PER CENT.

Type of Specimen	Cement Number[a]	Period of Drying				
		4 days	10 days[b]	25 days	3 months	1 yr
Concrete	2738	0.018	0.031	0.044	0.055	0.068
	2767	0.008	0.020	0.032	0.048	0.061
	Difference	0.010	0.011	0.012	0.007	0.007
Mortar	2738	0.075	...	0.124	...	...
	2767	0.050	...	0.084	...	...
	Difference	0.025	...	0.040	...	...
RELATIVE SHRINKAGE OF CEMENT 2738 IN TERMS OF CEMENT 2767						
Concrete	225	155	137	114	111	
Mortar	150	...	148	...	...	

[a] Cement numbers represent specific samples as given in the author's original data, available to the discusser.
[b] Values interpolated.

the fact that the range of reported values is quite large makes them reasonably comparable to concrete tests computed to the nearest 0.0005 percentage point.

Coefficients of correlation between mortar specimens dried 4 days and concrete specimens dried for various periods are given in Table VII. It will be noted that the highest correlation is shown with concrete specimens dried for 10 and 25 days.

A plot of 4-day drying shrinkage of mortar bars against 10-day shrinkage of concrete bars is shown in Fig. 5. The solid curve in this figure represents the linear relationship as determined by the method of least squares. The equation of this curve is:

$$M = 2.333C + 0.0015$$

where:

M = shrinkage of mortar bars after 4 days of drying, and
C = shrinkage of concrete bars after 10 days of drying.

The equation indicates that the curve intersects the ordinate at a point very near the origin.

The coefficient of correlation, r, is 0.502. This value, according to statistical tables, indicates that the probability of the observed relationship being due purely to chance is less than one in a thousand.

The analysis, therefore, establishes beyond reasonable doubt that the mortar test does, in fact, furnish a useful index of the performance of cement in service.

The standard error of estimate, shown by broken lines in Fig. 5, is 0.0118 and is

TABLE VII.—COEFFICIENTS OF CORRELATION.

Coefficients of correlation between the author's values of shrinkage of 1:2 mortar specimens at the age of 7 days (representing 4 days of drying) and shrinkage of 3 by 3 by 10-in. specimens of concrete after drying for various periods.

Time of Drying Concrete Specimens	Coefficient of Correlation, 1:2 Mortar Dried 4 Days	Significance Index
10 days (interpolated)	0.502	0.001
25 days	0.504	0.001
3 months	0.346	0.05
1 year	0.332	0.05

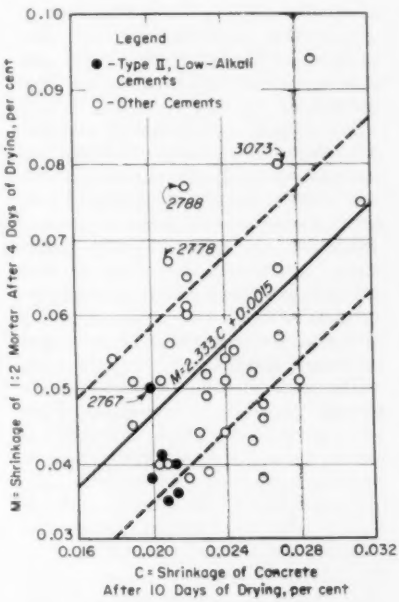

Fig. 5.—Relationship between drying shrinkage of 1:2 graded Ottawa sand mortar in 1 by 1 by 10-in. prisms dried 4 days and concrete in 3 by 3 by 10-in. prisms dried 10 days.

relatively large. Reasons for its largeness include the use of values for the concrete specimens that are reported to only two significant figures, and possible lack of reliability in reported values for the mortar specimens. Aside from failure of the author to make replicate tests of the mortars, there is evidence that the quantity of water used in these tests may not have been adjusted as precisely as desirable for correlation purposes. In 31 of the 40 mortar tests made, the water was added in multiples of 5 ml or to the nearest 1 per cent by weight of the cement. It is highly improbable that more than three-fourths of the cements would require an exact multiple of 5 ml of water.

The coefficients of correlation between mortar dried 4 days and neat paste dried 2 days and 6 days are 0.63 and 0.70, respectively. This indicates that the two types of specimens respond to drying in a highly similar manner.

The mortar tests of three of the cements, Nos. 2778, 2788, and 3073, are among those for which exceptionally high values of shrinkage were found. Mortar tests of these three cements, when compared to the neat-cement test results, are also high. The inference is strong, therefore, that had the tests been repeated, the mortar results for these three cements would have been lower and more in line with the least-squares curve of Fig. 5.

All of the type II, low-alkali cements gave concrete shrinkage values of less than 0.022 per cent. In the mortar tests, values of drying shrinkage are 0.041 per cent or less for all cements except No. 2767. The mortar test result for this cement is also high when compared with that for neat paste, suggesting possible inaccuracy of the mortar test.

Mr. Swayze's comments on autogenous volume change imply that this factor differentially affects the relative rate of water loss during drying of mortar and concrete specimens because of differences in original water-cement ratio. Apparently, he considers that autogenous volume change of itself constitutes a valid reason for rejecting pastes and mortars as test specimens for drying shrinkage.

The data for autogenous volume change, as given in the paper, have been plotted, and from the derived curves, values for ages other than those reported have been interpolated. The estimated values are shown in Table VIII. The increase in autogenous shrinkage beyond three days amounts to 0.8 per cent at 7 days and 1.1 per cent at 14 days. It is doubtful that autogenous volume changes take place at the indicated rate while the concrete is drying; but if they do, the amount is hardly sufficient to cause significant differences in the mortar and concrete tests.

Although the effect of autogenous action is to decrease volume, the author's data show that, with one exception, the lengths of all mortar and concrete and concrete specimens either remained constant or increased during moist curing. The conclusion is inescapable that other factors are acting on the paste in a direction opposite to that of autogenous volume change and that either they nulify or exceed it in overall effect.

In summary, the writer offers the conclusion that the author has not presented a good case against the use of mortar specimens to evaluate differences in shrinkage characteristics of cements. On the contrary, the data show a very high degree of correlation when evaluated in terms of concrete pavements and structures subjected to exposure out of doors.

TABLE VIII.—AUTOGENOUS SHRINKAGE.

Values are interpolated from the author's data and are shown as equivalent per cent water by weight.

Age, days	Cement Type I and II, Total	Cement Type I and II, Increase from 3 days	Cement Type III, Total	Cement Type III, Increase from 3 days
3	2.8	...	3.6	...
7	3.7	0.9	4.3	0.7
14	4.0	1.2	4.6	1.0

Mr. J. A. Kauer.[2]—About a year ago we encountered our first problem with shrinkage of cement paste. This resulted from cracking that developed in a concrete floor slab. We were told by the government agency concerned that the prevailing conditions of concrete placement, forming, and curing were such that it did not appear appropriate to attribute the localized areas of cracking to plastic shrinkage. Since the cement being used met all the specific requirements for a type I portland cement, it was thought the cause for the cracking might be found in the shrinkage characteristics.

A special test procedure was set up for cement pastes using autoclave bars, and measurements were made over a period of 7 days. This test showed that the cement used shrank more than the two other brands of cement, one being a type I and the other a type II cement.

A cooperative test was then carried out by three laboratories using one brand of cement. The test procedure followed a Method of Test for Expansion in Water and Contraction in Air of Portland-Cement Mortar[2] used by the Subcommittee on SO_3 Content of Committee C-1 on Cement. The three laboratories had very good agreement in all the results, as shown in Table IX.

After completing this series of tests, the agency suggested a shrinkage limit of 0.10 per cent at age of 72 hr for paste specimens and further stated: "A specification requirement developed as proposed should serve significantly in eliminating cements having comparatively high and objectional shrinkage characteristics. The results should be improved cement and concrete quality." My company decided to carry out a series of shrinkage tests on neat paste on all the brands of cement in our territories. Tests were run on 53 cements, of which 20 were type I, 16 type IA, 15 type III, 1 type IS, and 1 type II. Of the 53 cements, only 9, or 17 per cent, would pass the shrinkage requirement of 0.10 per cent at 72 hr.

The average shrinkage for the 20 type I cements at 72 hr was 0.110 per cent, and of the 20 cements only 7 had 0.10 per cent or less. The lowest shrinkage was 0.080 per cent and the highest 0.138 per cent.

For the 16 type IA cements the average shrinkage at 72 hr was 0.123 per cent, and of the 16 cements only one had 0.10 per cent or less. The lowest shrinkage was 0.094 per cent and the highest was 0.146 per cent.

For the 15 type III cements the average shrinkage at 72 hr was 0.126 per cent, and of the 15 cements none would meet the 0.10 per cent requirement. The lowest shrinkage was 0.104 per cent and the highest was 0.147 per cent.

For the type IS cement the shrinkage at 72 hr was 0.126 per cent; and for the type II cement 0.085 per cent.

We heartily agree with Mr. Swayze that cement paste and mortar shrinkage is meaningless, and that if shrinkage tests are to be made, they should be made on the concrete. In Mr. Swayze's excellent paper he definitely shows that no matter what shrinkage values you get with paste or mortars they are all about the same in concrete.

We hope that further work, showing the relationship between shrinkage of of neat cement paste, mortar bars, and concrete, be completed before serious consideration is given to establishing specifications on the shrinkage of neat paste or mortar bars.

Mr. M. A. Swayze (*author's closure.*)—This closure is intended to defend the position that short-term tests on either neat pastes or 1:2 standard sand mortars cannot be expected to predict the ultimate shrinkage behavior of portland cements in concrete. While the original intent of the paper was to cover the volume-change behavior of concrete in all sorts of exposures. Mr. Tremper's discussion is generally confined to con-

TABLE IX.—RESULTS OF SHRINKAGE TESTS.

Time	Laboratory	Shrinkage, per cent
	Cement Paste	
48 hr	No. 1	0.081
	No. 2	0.083
	No. 3	0.085
72 hr	No. 1	0.112
	No. 2	0.110
	No. 3	0.113
7 days	No. 1	0.171
	No. 2	0.161
	No. 3	0.176
	Mortar Bar	
48 hr	No. 1	0.021
	No. 2	0.022
	No. 3	0.026
72 hr	No. 1	0.035
	No. 2	0.034
	No. 3	0.040
7 days	No. 1	0.063
	No. 2	0.059
	No. 3	0.070

[1] Huron Portland Cement Co., Denver, Colo.

[2] *Proceedings*, Am. Soc. Testing Mats., Vol. 59, p. 366 (1959).

sideration of highway pavements, and bridges where the amount of lineal shrinkage is materially affected by relative humidity of the air and by the frequency of rainfall which will resaturate the concrete surfaces and therefore prevent drying shrinkage. Since the use of cement in highways is an important though minor part of cement sales in this country, this closure will be devoted largely to behavior of cement in concrete in such exposures.

For other uses, such as interior floors, beams, and other members of concrete structures and similar exposures where fog and rain cannot influence the internal humidity of concrete, the laboratory exposure of concrete specimens to 50 per cent RH air until shrinkage ceases cannot be seriously criticized. For specimens with a 3- by 3-in. section, this equilibrium occurs at about the age of 1 yr. Larger specimens obviously will require a longer time to reach ultimate shrinkage.

Air in the interior of buildings during the average American summer may be somewhat above 50 per cent RH at times, but moisture must be added to keep the humidity at this level during months when heating is required. One Colorado laboratory, for example, reported workroom humidities of 10 to 14 per cent some years ago during a cooperative test series on strength of cements, sponsored by the Subcommittee, on Strength of Committee C-1 on Cement. Even outdoor air can vary greatly in humidity, depending on location. For instance, I cannot forget the experience of following a truck hauling limestone from the Southwestern Cement Co. quarry near Victorville, Calif. about 15 years ago. The dust thrown up by this truck was strongly pungent and yet completely odorless. On being questioned about this strange phenomenon, our hosts explained that they had scattered calcium chloride over the road to hold down dust some 6 to 8 months prior to our visit. Up to that time there had not been enough moisture in the desert air to liquefy this deliquescent salt. Since crystalline calcium chloride is in equilibrium with its saturated solution and air at 31 to 32 per cent RH, the air over this quarry road must have had a much lower humidity than that required to melt the salt. Under such conditions, even outdoor concrete will dry and shrink faster than in the 50 per cent RH laboratory storage.

Mr. Tremper's discussion contains considerable reference to relative humidities which he found in the interior of concrete specimens, highway slabs, and bridge structures, but very little on shrinkages of concrete which he observed as related to these internal humidities. The single exception, except for references to the author's own data, regards a series of concrete specimens cast at Sacramento, Calif., in July, 1960. The larger specimens (14- by 20-in. and 4- by 5-in. beams) contained 6-sack concrete with 1½-in. maximum size aggregate and were exposed only to outside air. Smaller prisms were cast—3 by 3-in. specimens with aggregates larger than ¾ in. removed, and 1 by 1-in. prisms with all aggregate larger than ¼ in. out—and were exposed both to outdoor air and to 50 per cent RH laboratory storage.

TABLE X.—COMPARISON OF SHRINKAGES—1:2 MORTARS AND CONCRETES, PER CENT.

Cement Plant —Type	Mortar 3 to 7 days	Concrete 25 days	Concrete 88 days	Concrete 1 yr
Group 1				
2712A-II	0.035	0.032	0.052	0.064
2812H-II	0.036	0.031	0.045	0.063
2833B-IA	0.038	0.037	0.051	0.065
2810I-II	0.038	0.030	0.041	0.056
2713A-IIA	0.038	0.031	0.046	0.059
2832E-IIA	0.038	0.034	0.051	0.067
3107I-III	0.039	0.035	0.048	0.058
3020J-II	0.040	0.031	0.045	0.058
3037M-II	0.040	0.033	0.047	0.057
2762M-III	0.040	0.028	0.042	0.057
Average	0.038	0.032	0.047	0.060
Group 2				
2994D-II	0.041	0.030	0.044	0.058
2760I-I	0.043	0.033	0.048	0.059
2754E-II	0.044	0.033	0.050	0.062
2782K-III	0.044	0.034	0.045	0.062
2813A-III	0.045	0.030	0.044	0.061
3076I-I	0.046	0.037	0.047	0.057
2836A-IIIA	0.048	0.037	0.051	0.064
3098M-I	0.049	0.035	0.046	0.057
2767G-II	0.050	0.033	0.046	0.059
Average	0.045	0.033	0.047	0.060
Group 3				
2789H-IA	0.051	0.028	0.040	0.055
2838L-IA	0.051	0.036	0.051	0.063
2742D-II	0.051	0.040	0.050	0.063
2794L-III	0.051	0.032	0.049	0.062
2828F-IA	0.052	0.037	0.051	0.062
3078C-III	0.052	0.034	0.044	0.055
3048L-I	0.054	0.035	0.047	0.060
2990M-III	0.054	0.025	0.042	0.058
3113M-IIA	0.055	0.036	0.048	0.058
2801F-I	0.056	0.032	0.049	0.064
3075G-III	0.057	0.036	0.052	0.065
3114K-I	0.060	0.033	0.045	0.058
Average	0.054	0.034	0.047	0.060
Group 4				
2843F-IIIA	0.061	0.034	0.046	0.060
2817N-III	0.065	0.033	0.046	0.060
3066D-I	0.066	0.036	0.047	0.059
2778G-IIA	0.067	0.033	0.042	0.060
Average	0.065	0.034	0.045	0.060
Group 5				
2738D-III	0.075	0.042	0.053	0.066
2788D-III	0.077	0.033	0.043	0.061
2737D-I	0.077	0.040	0.052	0.066
3073D-IA	0.080	0.038	0.053	0.064
2839D-IA	0.094	0.042	0.059	0.069
Average	0.081	0.039	0.052	0.065

In reference to Mr. Tremper's text, his Table V, and Figs. 3 and 4 disclose that no rainfall occurred during the first 84 days of outdoor exposure. Internal humidities in the largest concrete specimens dropped very slowly during that time, with correspondingly little shrinkage. The 4 by 5-in. prisms, cast with the same concrete, begin to approach the author's shrinkages for similar concrete in 3 by 3-in. prisms at 28 days. His 3- by 3-in. specimens, containing ½-in. maximum-size aggregate, show higher 28-day shrinkages than even the greatest found for the 40 cements examined by our laboratory in 3 by 3-in. specimens made with up to 1¼-in. aggregates. His 28-day shrinkage of 1 by 1-in. prisms containing screened mortar is materially higher than our similar data on type II cements in a 1:2 graded Ottawa sand mortar and somewhat higher than our averages for other types. To us, this means that the relative humidity of the outdoor air in Sacramento during exposures through 56 days was on the average lower than 50 per cent. Figure 4, comparing shrinkages of outdoor and indoor specimens, leads to the same conclusion. It therefore appears valid to approve use of concrete shrinkages on drying of 3 by 3-in. prisms for at least 28 days as what might be expected in northern California. In the much more arid regions of southern California, a much longer stage of drying can be assumed. To attempt to estimate this shrinkage behavior of different cements after long periods and well-developed hydration in the cement paste of the concrete by drying mortar specimens for 4 days, after one day in molds and two more in water, is simply untenable. Hydration of the cement in these mortars is just getting well under way at the 7-day age. It cannot compare with cement hydration in concrete at 28 days, 3 months, or later ages.

Mr. Tremper's Fig. 5, in which he relates our data on mortar shrinkages after drying for 4 days to interpolated data on concrete shrinkages at 10 days, purports to have some mathematical significance. To this author, it is a typical shotgun diagram without significance. The accompanying Table X covering mortar and concrete shrinkages for each type of the 40 cements covered in our paper, shows all of the cements arranged in rising order of their mortar shrinkage after 4 days of drying, with corresponding individual concrete shrinkages after 25 days, 88 days, and 1 hr of drying. No mathematics can reconcile the comparative behaviors in mortars and concretes of cements in the first four groups. All five cements in group 5 are from the same plant. All five cements are high in C_3A and total alkali and relatively low in C_3S content, compared with cements of the same type from other plants. All of these factors are conducive to higher shrinkages in both mortars and concretes. Incidentally, the legend in his Fig. 5 regarding six of the type II cements being low-alkali products is somewhat misleading; actually only eleven cements out of the 40 of all types failed to pass requirements for low-alkali cement.

In Table VI, Mr. Tremper attempts to show correlation between relative shrinkages of one cement in concrete and in mortar with another. The high-

shrinkage cement is a type III product—the first cement in group 5 of Table X. The second is a type II product—the last in group 2. Since rates of hydration of these two types are vastly different, as discussed in our paper, the choice of these two cements for comparison is unfortunate. The accompanying Table XI covers three pairs of cements, with each pair of the same type, and with similar shrinkage characteristics in concrete, but with widely different 4-day shrinkages in 1:2 mortar. Many other similar comparisons could be selected, in which there is a complete lack of correlation between shrinkages of mortar and concrete.

It was asked whether our laboratory made repeat tests on mortar bars to check our averages on volume changes in the 3 bars molded from a single bath. In this particular series we did not. However, in developing our strict procedures for volume-change tests on all types of prisms, we have made numerous repeat tests to check our method and procedure in years past. If Mr. Tremper would similarly revise his own procedure to the same exact control of moisture during curing in molds and in control of humidity in the drying room, he would need neither four prisms per batch nor the running of repeat tests. In all cases our three individual mortar bar volume changes were within his standard deviation limits. One cannot obtain such concordant results with variable-humidity conditions during the 24-hr curing in molds, immersion of some specimens in water for 90 min and others for only 30 min prior to the initial 24-hr measurements, and finally, variation from 50 per cent RH by ±4 per cent during the drying tests, all of which are permitted in the official California test method.

An amusing misunderstanding of the author's views is found in the second paragraph of Mr. Tremper's discussion, in the statement that the newly adopted specifications on processing additions provide for determination of effect of additions on drying shrinkage by use of mortar specimens, and that by adoption of this test, the members of Committee C-1, in general, show that they do not share the views of the author on this subject. Nothing could be further from the facts. The truth is that the author was requested to prepare the first draft of this specification by the chairman of the Working Committee on Additions. In writing out this draft, very careful consideration was given to all of the various factors involved, and comparative mortar prisms were deliberately chosen to compare cement shrinkages between the addition cement and corresponding blank. The reason for this choice was that a cement in mortar showed larger shrinkage than the same cement in concrete. Another reason was the greater ease of mixing, casting, curing, and handling of such specimens. The original provisions in this section of the processing additions specification was that at any age of test, which ran through the age of 3 months, the shrinkage of the cement containing the addition at any age should not exceed that of the corresponding blank by more than 0.01 per cent. At subsequent meetings of the Subcommittee on Additions this strict limit was criticized by some members but successfully defended by the author. There is therefore no difference between the general views of Committee C-1 members and the author on this point, since the committee adopted the rigid requirements on relative shrinkage without debate.

The differences between the mortar shrinkage tests required by this processing additions specification and Mr. Tremper's proposed limits for acceptance of cements for California highway use are manifold. First, and highly important, the other limits on cements containing processing additions and corresponding blanks are highly restrictive. Both products must be made from the same lot of clinker and must show corresponding chemical compositions. Both must contain essentially the same SO_3 content and must be ground to essentially the same fineness. Under such conditions, variations in shrinkage can be attributed to the addition and to that alone. Further, comparative shrinkage tests are continued through 28 days up to the period of 3 months, and the subcommittee gave greater weight to these later tests than to performance after only 4 days of drying, in considering data on the first processing addition tested under this proposed specification.

On the other hand, the proposed California Highway Dept. limits on shrinkage of 1:2 mortars are limited to type II, low-alkali compositions. However, even with these restrictive limits there are other differences of enough magnitude so that the proposed limit of 0.04 per cent on shrinkage of 1:2 mortars after only 4 days of drying in air of 50 ± 4 per cent RH cannot possibly be relied upon to select the lowest-shrinkage cements for use in California highways.

TABLE XI.—RELATIVE DRYING SHRINKAGES, 3 PAIRS OF CEMENTS, PER CENT.

Type of Cement			Period of Drying			
Specimen	Number	Type	4 days	25 days	3 months	1 yr
Concrete:	3073D:	IA	0.015	0.039	0.054	0.065
	2833B:	IA	0.014	0.038	0.052	0.066
	Difference		0.001	0.001	0.002	−0.001
Mortar:	3073D:	IA	0.080	0.124		
	2833B:	IA	0.038	0.074		
	Difference		+0.042	+0.050		
Concrete:	2767G:	II	0.008	0.032	0.048	0.061
	2712A:	II	0.010	0.032	0.052	0.064
	Difference		−0.002	0.000	−0.004	−0.003
Mortar:	2767G:	II	0.050	0.084		
	2712A:	II	0.035	0.074		
	Difference		+0.015	+0.010		
Concrete:	2817N:	III	0.011	0.033	0.046	0.060
	3107I:	III	0.011	0.035	0.048	0.058
	Difference		0.000	−0.002	−0.002	+0.002
Mortar:	2817N:	III	0.065	0.102		
	3107I:	III	0.039	0.076		
	Difference		+0.026	+0.026		
Relative Shrinkages: Pairs of Cements, Per Cent						
3073D versus 2833B: (Type IA)		Concrete	107	103	104	99
		Mortar	210	168	...	...
2767G versus 2712A: (Type II)		Concrete	80	100	92	95
		Mortar	143	114	...	...
2817N versus 3107I: (Type III)		Concrete	100	94	96	103
		Mortar	167	134	...	...

A Fatigue Test for Printed Wiring Boards and Through Connections*

By G. R. GOHN and A. FOX

This paper describes how a Krouse plate fatigue testing machine was modified to permit the fatigue testing of printed wiring boards and through connections such as those used in miniature designs. A special monitoring circuit using a transistorized relay to indicate failure in the conductors is also described, and typical test data, in the form of strain cycle-life diagrams, are presented to show the usefulness of the test.

THE INCREASED complexity of electrical systems, coupled with size and weight limitations that have led to the miniaturization of many designs, have contributed to a marked increase in printed circuit applications in recent years. The electronics industry, in particular, has employed printed circuit boards in radio, television, and computer designs, and their use is widespread in communications systems, missiles, and satellites. In the last two, printed wiring boards and printed circuits are used, both in ground control equipment and in telemetering devices, where shock and vibration may cause fatigue. Such failure, even though it may lead only to intermittent opens in the electrical network, seriously impairs the reliability of the design and may cause failure of the entire system. Hence, it becomes desirable to know how these printed wiring boards will perform when subjected to shock and vibration in simulated life tests, while data on their fatigue characteristics become essential to a realistic appraisal of the performance capabilities of new designs.

Printed wiring (1,2),[1] the basis for printed circuit assembly, is a technique for making electrical connections between components by means of metallic foil strips bonded to the surface of an insulating material. The term "printed circuits," often used interchangeably with "printed wiring," implies that resistors, capacitors, and inductors are also printed. There are at least 20 known methods of producing printed wiring. By far the most popular method, and that used in the preparation of the samples covered by these studies, is termed the "etched foil" or photoetch technique. This process uses techniques similar to those used in the graphic arts industry, where the mechanics applicable to this type of manufacture have been well established. The basic copper-clad plastic raw materials had been under development by the laminating industry for a number of years before their commercial use for printed wiring boards and circuits.

Printed wiring boards are usually made from thermosetting laminates consisting of layers of paper, synthetic fibers, or glass cloth impregnated with resin and covered on one or both sides with thin metal foil, either rolled or electro-deposited. The cladding is usually bonded to the laminate with a thermosetting adhesive. Today, most printed wiring boards are clad with 2 oz copper per sq ft (0.0028 in. thick) which has been electroplated on a large lead drum, stripped therefrom, and bonded to the thermoset laminate. Thus, the metal has a coarse, columnar structure which seldom has good fatigue properties.

When the photoetch process is used to make printed wiring boards or test panels such as those used in fatigue tests from the metal clad laminate, an enlarged layout of the conductors or circuit is first prepared. This is then photographed and reduced to actual size with a precision copy camera, thus minimizing any drafting errors. A photo-sensitive lacquer or enamel, for example, KPR,[2] is applied to one or both copper surfaces from which the conductors are to be formed. When the negative containing the printed wiring circuit is placed over the sensitized surface and exposed to ultraviolet light, the sensitized material covering the conductor pattern is made insoluble in the developer while the remaining areas are soluble and are removed by the latter. Hence, when the board is placed in the etching solution, the copper is removed from the unwanted areas leaving the wiring circuit on an insulating base. The remaining conductors are then cleaned and coated with solder. By choosing different impregnating resins and fiber

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* Presented at the Sixty-fourth Annual Meeting of the Society, Atlantic City, N. J., June 25–30. 1961.

[1] The boldface numbers in parentheses refer to the list of references appended to this paper.

[2] Kodak Photoresist.

GEORGE R. GOHN is a member of the Research Dept., Bell Telephone Laboratories, Inc., New York, N.Y., and has been concerned with fatigue tests and the development of fatigue testing equipment for more than 30 years. He received his A.B. from Otterbein College in 1926, and a B.S. in engineering and a Met. Eng. degree from the School of Mines, Columbia University, in 1929.

ALFRED FOX has been concerned with fatigue and creep studies at the Bell Telephone Laboratories, Inc., since 1955. At the present time he is a senior in the Mechanical Engineering Dept. of Cooper Union.

reinforcements, the mechanical and electrical characteristics of these boards may be varied considerably.

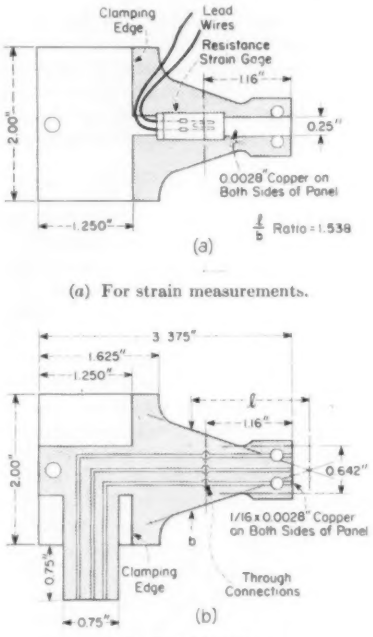
The typical cast structure of the electroplated metal cladding is further impaired, from a fatigue standpoint, by the solder coating, which tends to penetrate along the grain boundaries. Furthermore, the resulting product has an extremely low elastic limit so that, under cyclic or fluctuating strain, the stresses induced in the metal portion of the printed circuit board cannot be calculated from the laws of elasticity for the strains of interest. Instead, the problem becomes one of evaluating the effects of plastic strain resulting from the cyclic or fluctuating deflections imposed upon the composite board during test or under service conditions.

Very often it is necessary to provide a means to interconnect the printed wiring on opposite sides of the board. Through connections, either of the eyelet or the plated-through type, are used for this purpose. Eyelets most commonly used may be one of three kinds—flat-flange, rolled-flange, or funnel-flange. In all cases, however, a hole must be drilled in the base, that is, the dielectric or insulating material. The wall of this hole is then coated or the hole filled with conducting material to provide electrical continuity between conductors on opposite sides of the board. These holes in the printed wiring board cause stress concentration at or near the holes. These, in a duplex material, complicate the calculation of stress in the conductors and the connections on the basis of the established theoretical methods of stress analysis to such an extent that it is practically impossible to apply theory to the solution of the problem. Instead, it seemed desirable to develop an empirical test, and to analyze the test data statistically.

Materials and Test Specimens

The materials selected for test were printed wiring boards made from 36- by 48-in. panels of $\frac{1}{16}$-in. thick G-10 epoxy-glass laminate with a 2 oz per sq ft copper cladding (0.0028 in. thick) on both sides. These panels, obtained from the New England Laminates Co., were sheared into 4- by 5-in. rectangles and printed to give the conductor configurations shown in Figs. 1 (*a*) and 1 (*b*). After printing the circuit and etching away the unwanted copper, the cladding was roller coated with a 60:40 tin-lead solder giving a total metal thickness of about 0.003 in. on both sides of the laminate. In boards using a plated-through connection, a conducting medium is first applied to the drilled holes, usually electroless-deposited copper, followed by a deposit of 0.0015 to 0.0020 in. of copper applied by electroplating, after which the solder may be applied to the surface either by roller coating or to the surface and the holes by electrodeposition. Since the copper is deposited on the conductors as well as in the holes, electroplating will produce a conductor having an over-all thickness of as much as 0.006 to 0.008 in.

To test through connections, that is, connections made from one side of the board to the other by eyelets or by plated-through holes, special specimens were designed to include representative connections in the critically stressed area. These through connections may be tested as supplied or they may have wires inserted in the holes to simulate component leads which are usually fastened in place by solder dipping one side of the board. Either one of these conditions may be evaluated in the test described.



(*a*) For strain measurements.

(*b*) For life tests.

Fig. 1.—Fatigue test specimens for printed wiring boards.

The specimens themselves were designed around the familiar tapered cantilever beam which has been widely used in fatigue tests on metals. Essentially, the specimens have the same dimensions as those of the original Krouse-type fatigue specimen used by Gohn and Ellis (**3**) for their studies on lead-cable sheath. Two types are, however, required for fatigue tests on printed wiring boards: the one shown in Fig. 1 (*a*) is used for estimating the strain in the copper cladding as the specimen is subjected to fatigue; the one shown in Fig. 1 (*b*) has three $\frac{1}{16}$-in. wide conductors on either side of the specimen with one through connection in the center of each conductor. The use of the latter type of specimen permits testing three replicate specimens simultaneously. One edge of the clamped end of the specimen is extended to provide a means for making the electrical contacts required for the monitoring circuit, while metal pads in the clamping area are provided to increase the clamping surface and thus reduce the clamping stresses on the three conductors under test.

The specimens were prepared by cross-milling stacks composed of nine boards using a convex, fluted, carbide-tipped milling cutter. Epoxy-glass spacers with undercuts for the conductors and the eyelets (when present) were used to prevent crushing and to minimize edge and corner breakage during the milling operation.

Fatigue Testing Machines

The fatigue testing machines used were modified variable-speed (750 to 3600 cpm) Krouse flat plate fatigue testing machines as shown in Fig. 2. These machines subject the cantilever-

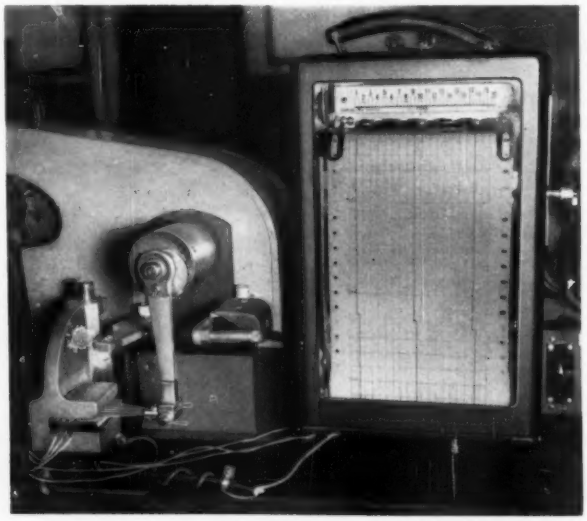


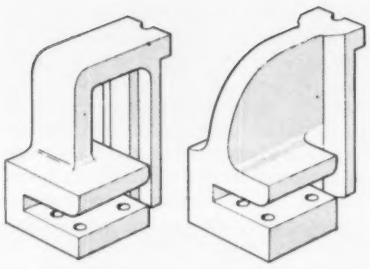
Fig. 2.—Close-up view of fatigue specimen and recorder.

beam specimens to reversed bending at constant alternating strain amplitude.

The nature of the material tested requires a considerably larger clamping surface than the $\frac{3}{4}$- by 2-in. area provided by the conventional Krouse plate or sheet-metal specimen. Since the work on lead sheath and high-purity aluminum led to the development of a specimen with a $1\frac{1}{4}$- by 2-in. clamping surface, this type specimen was tried and found to be satisfactory for testing printed wiring boards, provided additional pads are provided in the clamping area to reduce the clamping stresses on the three $\frac{1}{16}$-in. wide conductors. While the specimen itself (see Fig. 1 (*b*) is somewhat longer (3.630 versus 3.375 in.) than the conventional Krouse specimen, it was found necessary to further modify the design by using a generous radius on the clamp and by carrying the 2-in. width of the specimen beyond the clamping line to further reduce the stresses at the clamping edge. These two modifications combine to produce a tapered cantilever-beam specimen having an l/b ratio of 1.538 as compared to 1.812 for the standard Krouse specimen. In such a specimen the bending strain is constant throughout the 0.688-in. long tapered section.

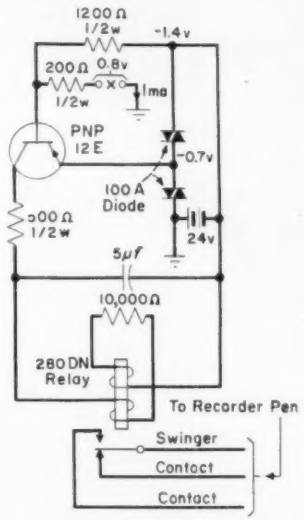
The over-all increase in length of the test specimen necessitates relocating the clamping block so that the distance from the center of the deflecting pin to the heel of the clamp is 3.880 in. rather than 3.625 in. Accordingly, the machined surface on the base of the Krouse testing machine where the clamp support is mounted must be extended to accommodate the new clamping block. The latter was designed as a doubly reinforced block as shown in Fig. 3 (*b*) to minimize bending stresses in the conventional type of U-shaped clamp. To facilitate alignment, three headless screws are fastened in the back of the clamp. These give a three-point contact between the clamp and the base and make possible the proper alignment of the clamp so that the neutral plane of the test specimen will also contain the axis of the deflecting pin. This can be checked by the use of a $\frac{1}{4}$-in. thick specimen having a contour similar to that shown in Fig. 1 (*a*) but made from ground steel gage stock. When the clamp is properly mounted and the deflecting cam set at zero deflection it should be possible to have perfect edge alignment of this steel specimen while it is in uniform contact with the upper or fixed part of the clamp.

In addition to the modifications required to permit the use of the test specimen shown in Fig. 1 (*b*) a suitable monitoring circuit must be provided. On the machines as manufactured, a mechanical counter registers the number of revolutions of the eccentric shaft in thousands. Fracture of the test specimen allows the deflecting arm to swing laterally; this operates a microswitch which in turn stops the testing machine. Since tests on printed wiring boards do not result in fracture of the laminate until the conductors or the plated-through connections have failed in fatigue, such a monitoring circuit is of no value for these tests.



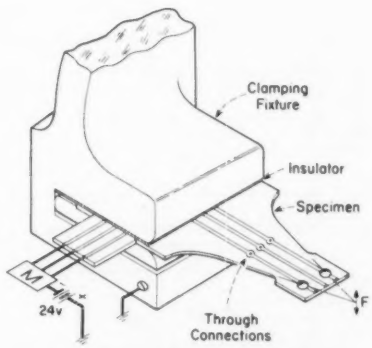
(*a*) Old clamp. (*b*) New clamp.

Fig. 3.—Clamping blocks.



Operation: With x closed, no current flows in relay winding; if x opens momentarily (0.003 sec minimum), transistor conducts, relay operates, and 5-μf capacitor charges. This charge holds relay operated at least 0.100 sec after x recloses. Current through specimen, 1.0 ma; voltage across specimen, 0.8 v.

Fig. 4.—Schematic circuit diagram for recording fatigue failures.



NOTE.—F is bending force applied to specimen through motion of variable throw cam, connecting rod, and yoke; M represents monitoring circuits.

Fig. 5.—Monitoring circuit for fatigue tests on printed wiring boards.

After considerable experimentation, the monitoring circuit shown in Fig. 4 was developed. This circuit will activate an Esterline-Angus voltage-type recorder when either the conductor or the through connection is open-circuited for a period greater than 3 millisec with 0.8 v applied to the test circuit. In this monitoring circuit, electrical connection is made by a common ground between the lower clamping plate of the Krouse machine and the three individual circuits, as shown in Fig. 5. The upper surface of the specimen is insulated from the clamping fixture by a phenolic plastic strip. The current thus enters the specimen conductors through the lower clamping plate, passes through the conductors on the lower surface, the through connections, and back through the conductors on the upper surface of the specimen. It then passes through individual circuits similar to that shown in Fig. 4. If open-circuiting occurs at any time during the constant-amplitude fatigue test, this is recorded on the automatic chart of the Esterline-Angus recorder which is normally set to travel at a speed of 3 in. per hr. The first sign of open-circuiting is taken as failure of that particular conductor or through connection. The test is continued until open-circuit conditions are recorded for each of the three test circuits.

For circuits that respond to intermittent opening times of less than 3 milliseconds, the cycles-to-failure indicated by the test circuit shown in Fig. 4 may give a somewhat optimistic estimate of life. If opening times of shorter duration are of interest, then the monitoring circuit must be modified. By introducing a broadband amplifier and a high-speed multivibrator ahead of the 280 DN relay (Fig. 4) the circuit can be made to respond to opening times in the microsecond range.

Test Procedure

To make a fatigue test on printed wiring boards the relation between the deflection of the free end (the deflected end) of the specimen and the strain in the outer fibers of the metal conductors must first be established. To determine this relationship the specimen shown in Fig. 1 (*a*) is used. Type

C9-131 foil-type resistance strain gages having an active length of 0.187 in. (over-all length = 0.375 in.) are cemented to the $\frac{1}{4}$-in. wide copper strip on both sides of the test specimen, and the specimen is deflected by hand through various cam settings. Such gages have a negligible stiffening effect upon a test specimen of the thickness used in these studies. The total strain output per cycle is read on a strain indicator for deflections ranging from 0 to ±0.500 in. A dial indicator is used to measure the vertical displacement of the connecting rod to the nearest ±0.001 in. (Strains determined statically were checked by dynamic methods in which the output of the strain gage was fed into an oscilloscope, and the static and dynamic strains corresponding to the deflections of interest were found to be in good agreement at the testing speed used, about 1800 cpm.)

The test specimen (Fig. 1 (*b*) is then mounted in the machine and tested until failure is indicated by the monitoring circuit. Various deflections are used so that a strain-cycle curve (similar to an *S-N* diagram) may be plotted. Technically, the copper strip should be tapered if uniform stress is desired in the conductors throughout the critical section. However, the copper conductors are so thin and so soft, that is, the elastic limit is so low, that they offer very little resistance to deformation under the applied load. Hence, their effect can be neglected and it may be assumed that the bending moment is resisted almost entirely by the epoxy laminate.

The strain in the copper conductors and the epoxy laminate at the interface is the same, since there was no observable slip in the bonding medium. The conductors themselves are plastically deformed for most of the vibration amplitudes (deflections) of interest. Under these conditions the strain in the conductors becomes a better criterion than stress for the evaluation of fatigue characteristics. Furthermore, the strain in the outer fibers of the conductor is directly proportional to the over-all thickness of the laminated sheet plus the cladding, hence strain rather than stress is taken as the independent variable in those fatigue tests.

The strains of interest were determined from strain measurements made on typical printed circuit boards containing two large capacitors weighing 11 g each and tested on an MB C-25H vibration machine. The boards were mounted on six $\frac{3}{8}$-in. diameter standoffs to a large flat circular aluminum plate. This plate in turn was bolted to the table of the vibration machine so that the major axis of the printed circuit boards was in a horizontal plane. Foil strain gages were used to measure the strains as the boards were first tested at basic frequencies of 30, 60, 500, and 2000 cps at a constant acceleration of 10 *g*. These tests were then followed by a sweep between 0 and 2000 cps at an acceleration of 10 *g* in order to locate the range of resonant frequencies. The maximum strain observed in these tests was 0.002. The tests were repeated with components mounted in various positions and also with components bonded to the boards with epoxy resin[3] and curing agent T-1. In these tests the observed strains were substantially reduced.

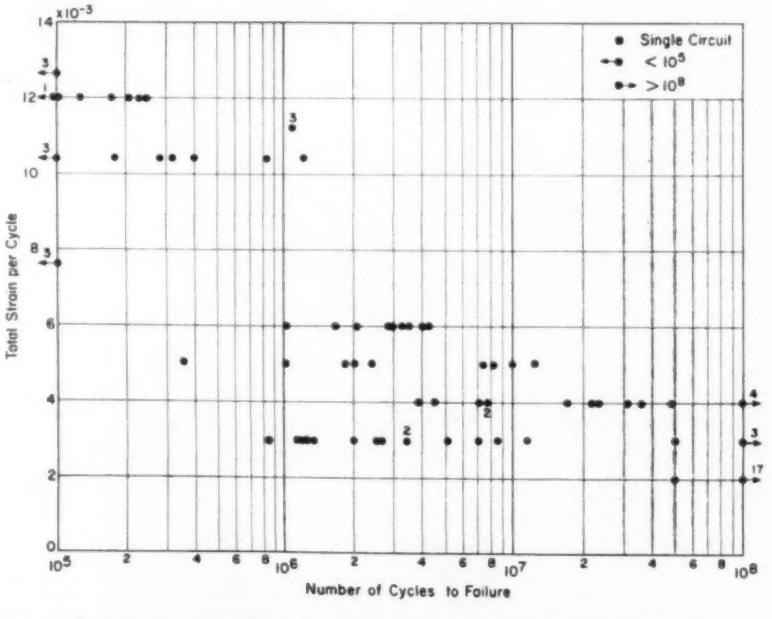
In general three or more specimens similar to those shown in Fig. 1 (*b*) were tested at each strain level. This yields nine or more datum points.

Test Data

Typical test data for printed wiring boards made from the copper-clad G-10 epoxy glass laminate are shown in Fig. 6. These data were obtained before the monitoring circuit shown in Fig. 4 was developed. Since the original monitoring circuit used an Esterline-Angus voltage-type recorder in series with the test specimen, 24v dc was impressed on the copper conductors. With this circuit, intermittent opens were not detected unless they were of 15 millisec or longer duration. Thus, these tests show a cycle life approximately 1.5 to 2.0 decades higher for the strain levels studied than the cycle lives noted in subsequent tests at the same strain levels when the transistorized monitoring circuit was used.

The material tested had an elastic limit of less than 5000 psi. For such material the strain would be approximately 0.0003 at the elastic limit. If this strain is deducted from the values of strain shown in Fig. 6 and the data replotted as log total plastic strain versus log cycle life, a linear relation is obtained. This straight line has a slope of $-\frac{1}{4}$, a value which differs considerably from the $-\frac{1}{2}$ reported by Low (**4**) and by Tavernelli and Coffin (**5**). A similar plot of the data obtained on boards having no through connections and using the transistorized recording circuit yielded a straight line with a comparable slope.

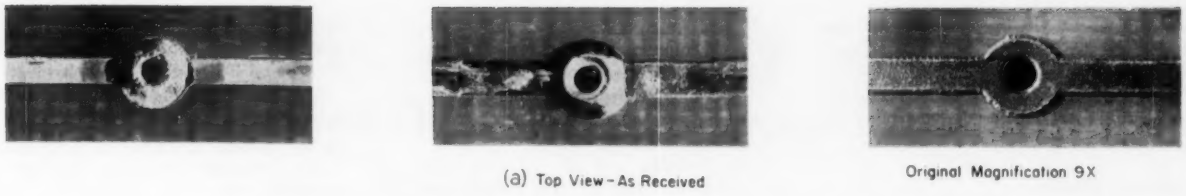
The boards used in the tests for which data are reported in Fig. 6 were roller-coated with 60:40 tin-lead solder and had flat-flange eyelet-type through connections. Other boards, particularly those with plated-through connections, are first electroplated with copper and then with solder. Representative through connections made with peened eyelets, funnel-type eyelets, and by electroplating are shown in Fig. 7. The "as received" condition is shown in plan view in Fig. 7 (*a*) and in cross-sectional view in Fig. 7 (*b*). Figure 7 (*c*) shows typical fatigue failures after cycling at a strain of ±0.004. Typical fractures in the conductors on both types of printed wiring boards are shown in the photomicrographs (Fig. 8). These clearly reveal the large dendritic nature of the copper, the penetration of the solder along the grain boundaries, and the intergranular nature of the fatigue cracks. This is contrary to the usual fatigue failures at

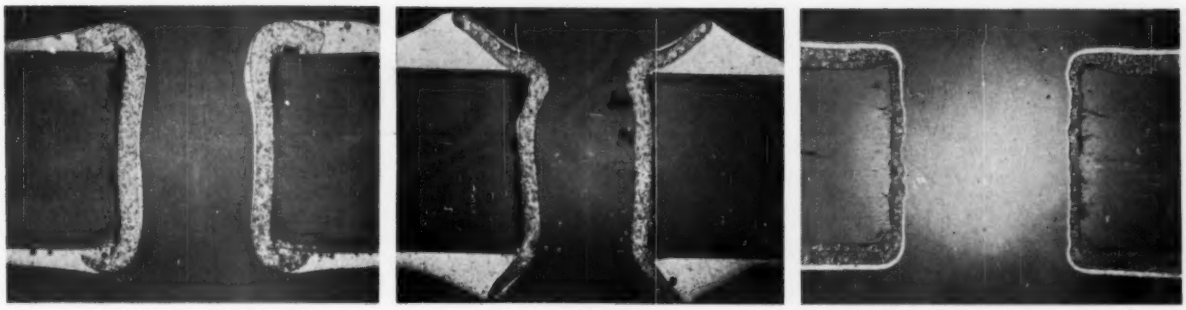


$\frac{1}{16}$-in. thick epoxy-glass, 2 oz copper-clad printed wiring boards with flat-flanged eyelet through connection; tested at 1600 cpm and 85 F.

Fig. 6.—Typical fatigue test data.

[3] Epon 828, Shell Chemical Co.





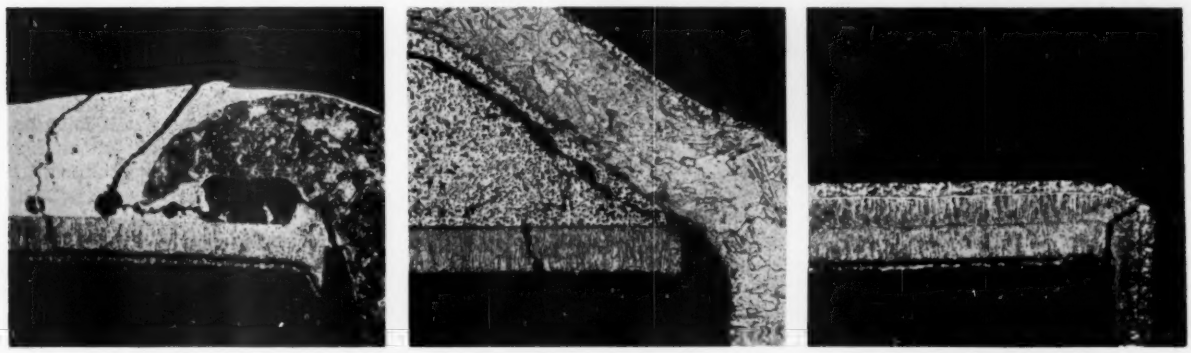
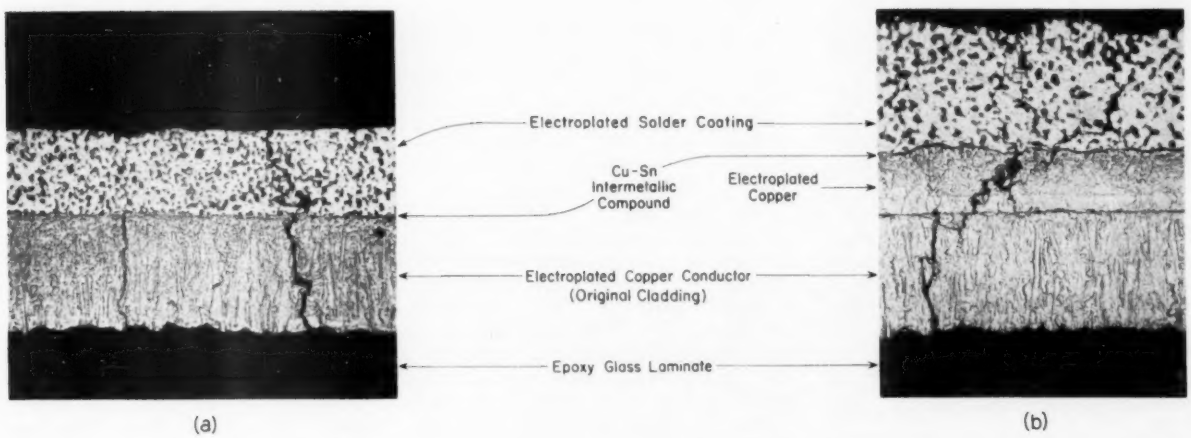


Fig. 7.—Typical through connections used on printed wiring boards (reduced one half for publication).



(*a*) Conductor used with eyelet-type through connection. (*b*) Conductor used with plated through connection.

Fig. 8.—Typical fatigue failures at ±0.004 strain in printed wiring board conductors. (Original magnification 500 ×; reduced one half for publication).

stresses within the elastic range, where the fatigue fractures are transcrystalline, but agrees with the findings reported by Gohn and Ellis (3) for lead sheath subjected to fatigue at slow cycling in the plastic range.

Acknowledgments:

The authors are indebted to Mr. M. J. O'Brien for the metallographic studies made in connection with these tests and for the preparation of the photomicrographs used in Figs. 7 and 8; to Messrs. J. W. Buckelew and W. G. Bader who made the vibration studies; and to Mr. R. L. Pentland for his assistance in the design of the monitoring circuit.

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Discussion of Paper on Determination of the Mechanical Properties of Elemental Sulfur[1]

MR. HUBERT WOODS.[2]—Mr. J. M. Dale's paper, "Determination of the Mechanical Properties of Elemental Sulfur," was very interesting and instructive.

The reported strengths come somewhat as a surprise to those of us who are not familiar with sulfur. The comparison with strengths of concrete, with which many are more familiar, is a useful device, but one could wish that the figures used for concrete, in particular the tensile strength, were more representative. The figure given for tensile strength of concrete, namely 150 psi, is characteristic of a very poor concrete indeed—one that would have a compressive strength well below 2000 psi.

In their book, *Composition and Properties of Concrete*, (McGraw-Hill, New York, N.Y. 1956) G. E. Troxell and H. E. Davis give information on the tensile and compressive strength and modulus of rupture of concrete. They show that for a compressive strength of 3000 psi, the figure cited by Mr. Dale and commonly used for purposes of general discussion, the corresponding tensile strength would be about 270 psi rather than the 150 psi used. Modern techniques permit the production of concrete having a compressive strength of 8000 psi or more, with tensile strengths on the order of 600 psi.

MR. PETER R. KOSTING.[3]—Data in the paper indicated that tensile strengths of about 100 g per sq mm were obtained. These values compare with strengths reported in the European literature as high as 11,000 g per sq mm for specimens in the form of filaments approximately 1 mm thick. This type of tension specimen is vastly different from that used by Mr. Dale.

This prior work reported in the literature indicated the importance of knowing the thermal history of the sulfur, particularly the maximum temperature to which it was heated prior to pouring and the time lapse between cooling and testing.

I hope that the reference in the paper about the lack of information in the literature on the mechanical properties of sulfur does not imply what it stated.

It is pleasant to know that there are others interested in the mechanical properties of sulfur.

MR. J. M. DALE (*author*).—In earlier correspondence with the Portland Cement Assn. we were advised that the 3000 psi compressive strength quoted in the paper was an acceptable figure. In addition, various handbooks on the strength of concrete quote comparable figures. For example, Merriman and Wiggin's *American Civil Engineers' Handbook*, John Wiley & Sons, Inc., lists on page 550 the ultimate strength of 1:2:4 portland-cement concrete as 150 psi in tension and 2000 psi in compression. Similar figures can be found in numerous handbooks and other publications. It is quite well accepted that under special laboratory conditions 6000 psi compressive strength concrete can be made, but it must be emphasized that we were attempting to compare run-of-the-mine sulfur with run-of-the-plant concrete.

Our work on this subject was prompted by our need for the strength properties of run-of-the-mine elemental sulfur so that we might investigate the feasibility of building a sulfur ship as a new means of transporting sulfur. This work, incidentally, is to be published shortly in *International Shipbuilding Progress*. The scope and results of our investigation of the mechanical strength properties of sulfur was therefore sufficient to allow us to proceed on this other study.

Since publication of the paper, we are finding that the strength properties of crude elemental sulfur can, indeed, be greatly increased by controlling the melt temperature and cooling rate. This was implicit in the report in the paper that various of the specimens had strengths from 50 to 100 per cent greater than average.

Mr. Kosting points out that studies conducted in Europe on sulfur filaments indicate strengths as great as 100 times those found by us for sulfur in the bulk form. This is not unexpected, since it is well known that single crystals, "whiskers" and the like, of any material give strengths far in excess of the strengths found for the same material in the bulk form.

All of this indicates that sulfur of the future will possibly be produced in various strength grades, most of which will be above the strength of concrete, and therefore our comparison with concrete was all the more striking.

[1] John M. Dale, "Determination of the Mechanical Properties of Elemental Sulfur," *Materials Research & Standards*, Vol. 1, No. 1, Jan., 1961, p. 23.

[2] Director of Research, Portland Cement Assn., Skokie, Ill.

[3] Lecturer, College of Engineering, Duke University, and Metallurgy and Ceramics Div., U.S. Army Research Office, Durham, N. C.

A Technique for Observing Structure-Soil Interaction

By E. T. SELIG

DIRECT VISUAL observation of the interaction of soil with various structural members such as foundations, tunnels, buried shelters, and retaining walls is often very valuable, if not essential, in understanding the mechanics of the system. This article describes a technique which has been used successfully by the author to observe, two dimensionally, the behavior of several of these soil-structure systems.

The apparatus is shown partially disassembled in Fig. 1. Basically it consists of a soil container with removable plate-glass sides, each 18 in. high and 24 in. long, spaced 4 in. apart. The upright portion in Fig. 1 is the basic frame of the box with one of the glass sides in place. This frame is made of 5-in. aluminum channel with a recess provided for the glass plates. The other glass side is shown in front of the box lying on top of the 2-in. aluminum angle frame which is used to fasten it to the box. The assembled box ready for use is shown in Fig. 2. A grid of lines on the surface of the soil adjacent to the glass makes it possible to observe the movement of the soil that takes place parallel to the glass.

Experience with the apparatus has shown that a low enough coefficient of friction can be attained between the soil and glass to permit good simulation of two-dimensional behavior. As the transparent medium for the sides of the container, glass has the advantage, compared with plastic, for example, of not being easily scratched, hence maintaining optical clarity for photographic purposes.

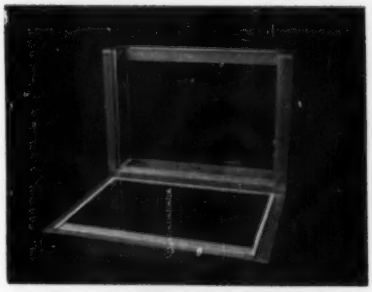

Fig. 1.—Unassembled glass box.

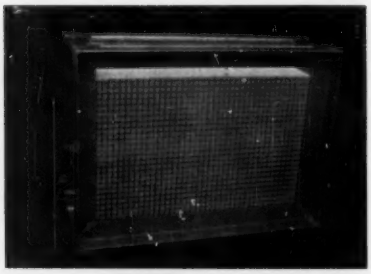

Fig. 2.—Assembled glass box ready for use.

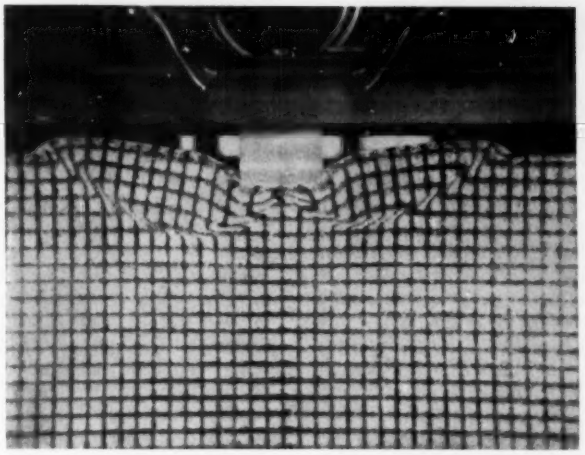

Fig. 3.—Symmetrical failure of sand beneath surface footing.

Examples of Application

Figure 3 shows the symmetrical failure of soil beneath a surface continuous footing when the bearing capacity has been reached. To achieve this result, the box was filled with dense, dry sand. In this model the vertical sand surface containing the grid represents a vertical plane through a bed of soil. The block, representing a section of a long footing, was cut to fit the 4-in. distance between the glass plates, then placed on the sand surface and loaded vertically. To ensure symmetry of failure, the block was constrained against rotation.

Figure 4 shows a one-sided failure of soil beneath a buried continuous footing. The model used was the same as for the surface footing except that the block was initially buried in the sand to a depth equal to its width (2 in.) and was not prevented from rotating.

Figure 5 shows the failure of a stratified soil beneath a surface continuous footing. As in Fig. 4, this footing was not constrained against rotation; hence a one-sided failure occurred. In this case the soil was a stiff, compacted clay which failed along horizontal planes of

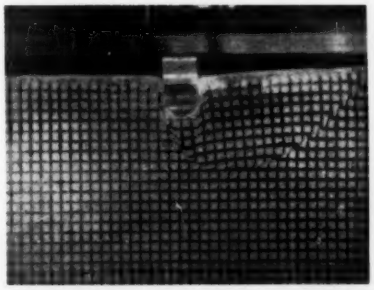

Fig. 4.—One-sided failure of sand beneath buried footing.

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E. T. SELIG is an associate research engineer at the Armour Research Foundation of Illinois Institute of Technology, Chicago, Ill. He received a B.M.E. degree from Cornell University in 1957 and an M.S. in mechanics from Illinois Institute of Technology in 1960. At Armour he has been responsible for a number of research studies in mechanics and helped to establish the soil mechanics laboratory. His recent efforts have been devoted to static and dynamic experimental studies of structure-soil interaction problems. He is also completing the requirements for a Ph.D. in soil mechanics.

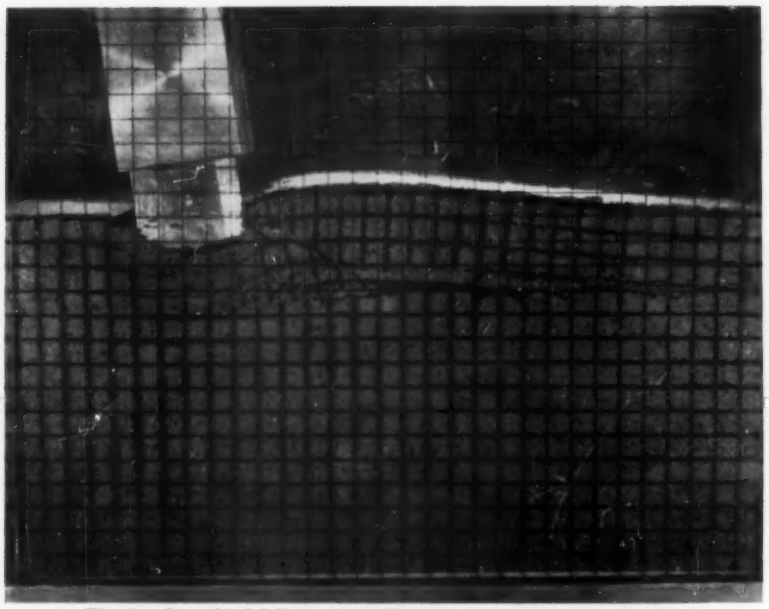

Fig. 5.—One-sided failure of stratified clay beneath surface footing.

weakness, except in the immediate vicinity of the footing. For this test the initial position of the grid was marked by another identical grid inked on a thin sheet of transparent plastic. In order to minimize parallax between the reference grid and soil grid and to protect the inked grid, a second 18 by 24-in. sheet of glass $\frac{1}{8}$ in. thick was placed inside the $\frac{1}{2}$-in. glass plate with the inked grid inserted between the two. This $\frac{1}{8}$-in. glass sheet also served another useful purpose: it acted as a disposable glass liner which could be inexpensively replaced if scratched or cracked.

The failure of a dense, dry sand accompanying the yielding of supports of a deeply buried rigid roof panel is shown in Fig. 6. The exposed surface of sand containing the grid represents a vertical plane through a bed of soil. The structural model, made to fit the space between the two glass sides of the container, consisted of a stiff, horizontally oriented plate (shown in black) which moved downward between two rigid vertical walls (white). Initially the roof panel was positioned at the top of the walls.

Figure 7 shows the effect of the yielding of a simply supported, buried, flexible wall panel. The vertical wall panel, represented by a flexible piece of sheet steel, was initially straight. The vertical support to the left of (behind) the panel was used to control the yielding.

Preparation for Tests in Sand

After assembly of the box, the first step in preparing for tests with sand was to fill the glass box with sand at the desired density. Where buried structural models were used, these were placed in the container before any sand was added. The sand may be put in loose or vibrated to a higher relative density. It can be vibrated by clamping a flexible-shaft concrete vibrator to the top of the box, with rubber pads between the vibrator and the container and also beneath the container to reduce the force of vibration and to vibrate the entire body of sand effectively.

Following placement, the surface of the sand was carefully levelled and smoothed by means of an appropriately shaped scoop. After a retaining plate was clamped in position on the top surface of the sand, the glass box was placed on one of its sides and the exposed glass plate removed. It is shown at this stage in Fig. 8. The top retaining plate must fit precisely against the sand surface; otherwise when the box is placed on its side a shifting of sand will occur next to the plate. This is an undesirable disturbance of the sand which will not only influence the results of the test but which will also cause the grid lines near the surface to diffuse when the box is later set upright.

The grid lines were located by means of a slotted marking frame placed over the exposed sand surface as shown in Fig. 9. Some of the same sand dyed with India ink was then sprinkled onto the marking frame with a salt-shaker (Fig. 9). Parallel lines $\frac{1}{16}$ in. thick spaced $\frac{1}{2}$ in. apart were formed on the exposed sand surface by the dyed sand which fell through the slots in the frame. During this operation the frame must be flush against the sand to prevent scattering of the colored sand as it falls

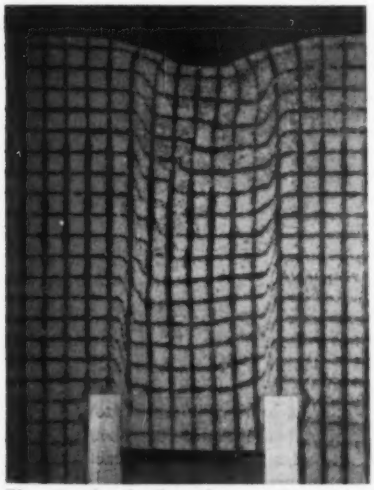

Fig. 6.—Sand distortion accompanying yielding of a rigid roof panel.

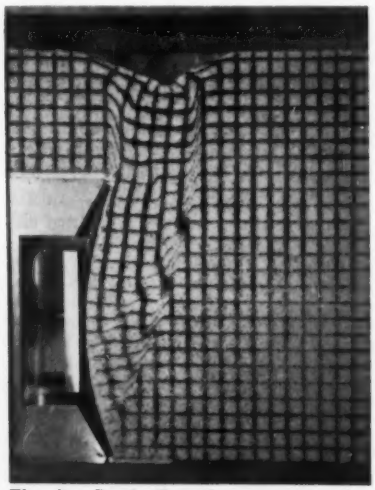

Fig. 7.—Sand distortion accompanying yielding of a simply supported flexible wall panel.

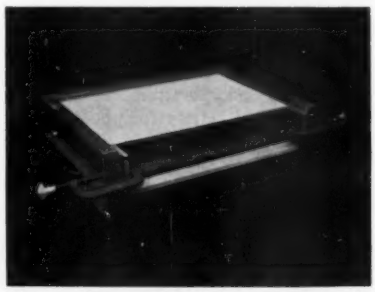

Fig. 8.—Box prepared for marking grid lines.

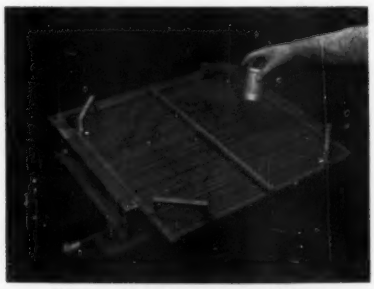

Fig. 9.—Marking the grid lines.

through the slots, but not pressing against it so as to disturb it. Otherwise the glass plate when replaced will not fit tightly against the sand, a factor which will also cause disturbance when the box is set upright. The square grid was completed by rotating the marking frame 90 deg and repeating the marking procedure.

After the grid was completed, sand grains were carefully removed from the seat into which the glass plate fits to ensure that the glass would fit flush against the sand. The glass plate was then replaced, the box was set upright, and the top retaining plate was removed. The apparatus was then at the stage shown in Fig. 2.

Preparation for Tests in Clay

A falling-weight compaction hammer was used to prepare cohesive soil specimens in the glass box. The arrangement for compaction is shown in Fig. 10, where the hammer may be seen extending down into the box. The upper portion of the machine is the mechanism for automatically raising the hammer a constant distance above the soil and releasing it. The face of the hammer was 2 by 4 in., the latter dimension spanning the distance between the two glass sides. After each blow the box was progressively indexed along a roller track beneath the point of fall

Fig. 10.—Equipment for compaction of clay.

of the hammer so that each blow overlapped the preceding one. The rectangular extension on top of the box was for guiding the hammer when the level of the soil was near the top of the box. For uniformity of compaction only complete passes were made. The hammer weight, drop height, and thickness of layers were varied to change the density of the soil. The inside surfaces of the glass plates were coated with a film of grease to reduce the adhesion of the clay to the glass.

After the clay was compacted to the desired height in the box, the clay surface was scraped smooth and the top retainer plate was clamped in place. The procedure used for applying the grid lines was the same as that described for sand. After the grid was completed, the box reassembled, and the test fixtures placed, the open top of the glass box was covered with a plastic membrane to seal in the moisture, thus maintaining the clay specimen at a constant moisture content throughout the test.

Discussion

This technique is a useful tool for the study of many important problems in soil mechanics and may also be valuable as a teaching aid. Experience has shown that good two-dimensional representation can be achieved with this apparatus. In addition to the examples of application given, the apparatus has also been used for examining the behavior of footings under dynamically applied loads and buried structures collapsed by a static overpressure on the soil surface. A comparison was made of the bearing capacity on sand of model footings having a large length-to-width ratio with the bearing capacity of an equal-width footing in the glass box under the same soil conditions. The resulting bearing capacities from these two analogous tests were within 5 per cent, indicating that quantitative as well as qualitative information can be obtained.

Acknowledgments:

The apparatus was designed and built at Armour Research Foundation under the sponsorship of the Air Force Special Weapons Center, Albuquerque, N. Mex., for research studies in soil mechanics. The concept of a soil container with transparent sides has been used by other investigators, for example Loos and Breth,[1] Sylwestrowicz[2] and Jumikis.[3] The techniques described in this article have been developed to more fully exploit this concept.

[1] W. Loos and H. Breth, "Kritische Betrachtung des Tunnel und Stollenbraues und der Berechung des Gebirgsbruckes," *Der Bauingenieur*, Heft 5, 1949, pp. 129–135.

[2] W. Sylwestrowicz, "Experimental Investigation of the Behavior of Soil Under a Punch or Footing," *Journal of the Mechanics and Physics of Solids*, Vol. 1, 1953, pp. 258–264.

[3] A. R. Jumikis, "Rupture Surfaces in Sand Under Oblique Load," *Journal*, Soil Mechanics and Foundation Div., Am. Soc. Civil Engrs., Vol. 82, Jan., 1956, pp. 1-26.

Characteristics of Moisture Deposition on Corrosion Specimens

By P. J. SEREDA

Records of the appearance of the moisture on specimens of various metals exposed outdoors to rain or dew show that the moisture may involve a wide size range of water droplets or films and that the conditions are transient. Thus no single state represents the physical character of the moisture on the surface of an exposed metal specimen during any period of wetness.

The average temperature of the specimens during the time of wetness was less than 1 F below the air temperature. Thickness had a slight effect on the average temperature of clean specimens. This effect was cancelled when the surface was covered with corrosion products.

MOISTURE IS AN essential factor in the process of corrosion (1),[1] and a study of its physical characteristics, when it is deposited as rain or dew on the surface of metal specimens exposed to the atmosphere, should prove fruitful. Such information would be particularly useful when attempting to

[1] The boldface numbers in parentheses refer to the list of references appended to this paper.

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TABLE I.—DESCRIPTION OF SPECIMENS.

Metal	Thickness, in.	Surface Condition
Series I		
Steel	0.1	Corroded
Zinc	0.1	Corroded
Stainless steel	0.065	Shiny
Steel electroplated with zinc	0.035	Clean, mat
Copper	0.037	Slightly tarnished
Galvanized steel	0.017	Spangled
Aluminized steel	0.030	Clean, mat
Series II		
Zinc	0.3	Grit blasted
Zinc	0.2	Grit blasted
Zinc	0.1	Grit blasted
Zinc	0.05	Grit blasted
Zinc	0.025	Grit blasted
Steel	0.1	Corroded
Steel	0.025	Corroded

reproduce atmospheric conditions in the laboratory.

In this study, time-lapse photography was used to record the appearance of rain and dew on the surface of metal specimens. The surface of the exposed specimens was photographed every ½ hr starting less than 1 min after the moisture was detected by the moisture-sensing elements developed in this laboratory (**2,3,4**).

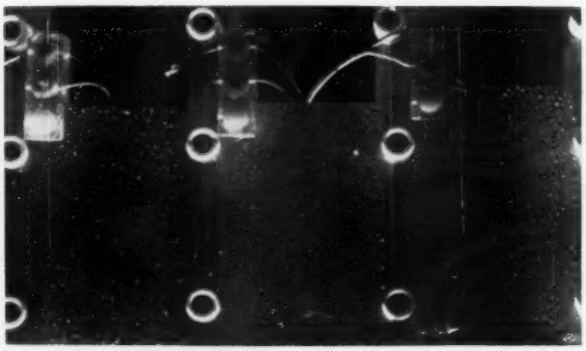
The temperatures of the specimens were recorded during the time of wetness to show the effects of the different metals and different thicknesses of the same metal. The air temperature was also recorded for the same period.

Experimental

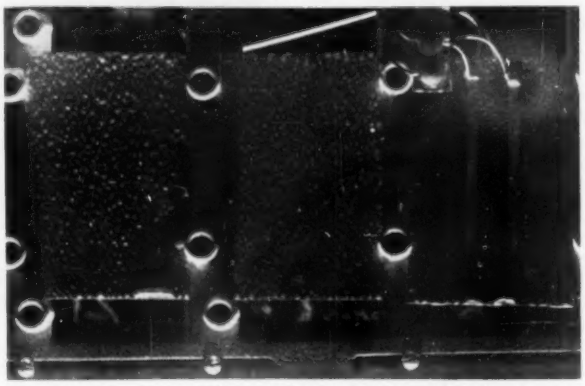
Metal specimens 4 by 6 in. were exposed on a standard corrosion frame at 30 deg to the horizontal. Most of the specimens had a thermocouple mounted on the groundward side connected to a multipoint Speedomax recorder. The specimens are described in Table I.

Mounted along with both series of specimens there was a moisture-sensing element which consisted of a zinc plate with platinum-foil electrodes secured to the two surfaces in the manner described previously (**2,3**).

A special 35-mm camera was mounted on a frame about 4 ft above the specimens. It was shielded by a plastic hood, and a small heater was provided inside the hood to prevent condensation on the lens. An electronic flash was mounted on a boom about 6 ft to the side of the specimens. In order that the light would strike the specimens tangentially, the axis of the light reflector was in line with the top surface of the specimens. A mechanical timer developed in this laboratory was used to provide the time-lapse, which was ½ hr for most of the experiments. The timer and the camera exposure and rewind mechanism were started by the relay of the amplifier in the moisture-sensing system (**4**).



(*1*) Zinc, 0.10 in. (*2*) Stainless steel, 0.065 in. (*3*) Zinc-plated steel, 0.035 in.



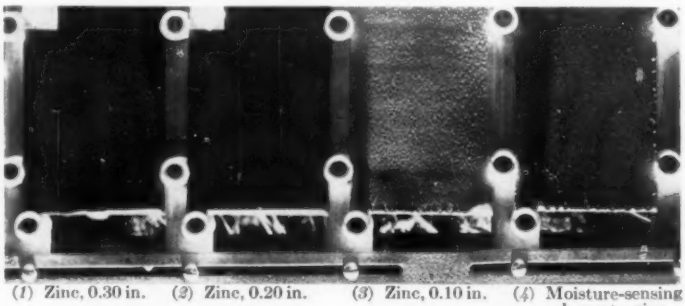
(*4*) Moisture-sensing element, zinc, 0.10 in. (*5*) Aluminized steel, 0.030 in. (*6*) Galvanized steel, 0.017 in.

Fig. 1.—Dew formed on specimens of different metals.

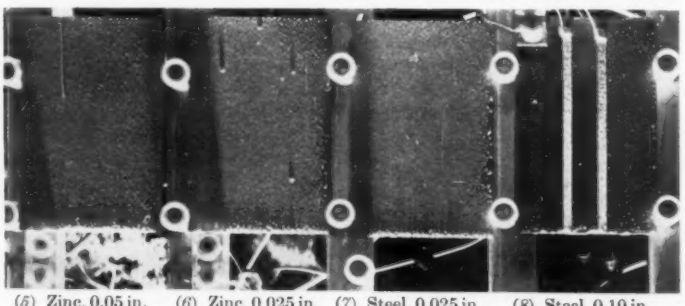
Copper-constantan thermocouples, No. 30 gage, were taped with Scotch electrical tape No. 56 to the groundward side of the specimens and were connected to a Speedomax recorder. The recorder was run only during the time of wetness, being started and stopped by the action of the relay in the amplifier of the moisture-sensing system.

Test Results

The sensitivity of the moisture-detect-



(*1*) Zinc, 0.30 in. (*2*) Zinc, 0.20 in. (*3*) Zinc, 0.10 in. (*4*) Moisture-sensing element, zinc, 0.10 in.



(*5*) Zinc, 0.05 in. (*6*) Zinc, 0.025 in. (*7*) Steel, 0.025 in., corroded (*8*) Steel, 0.10 in., corroded

Fig. 2.—Dew formed on specimens of zinc and steel of different thicknesses.

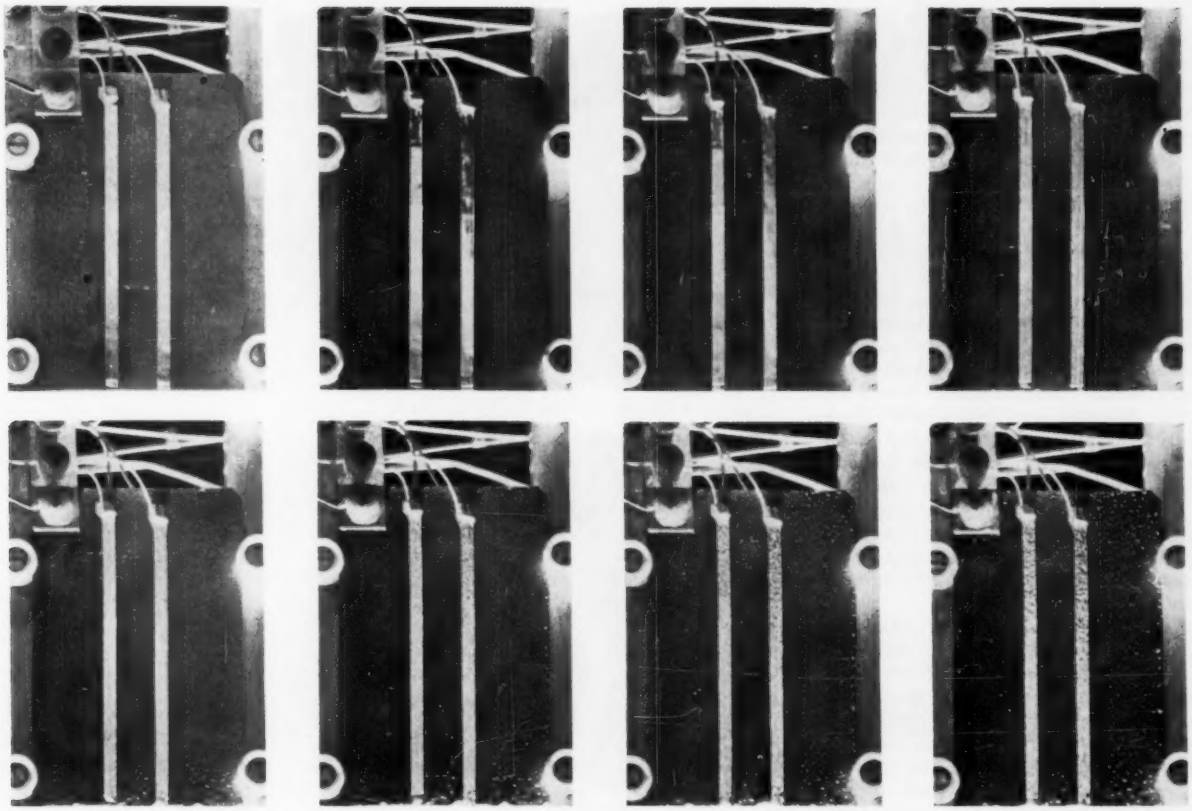
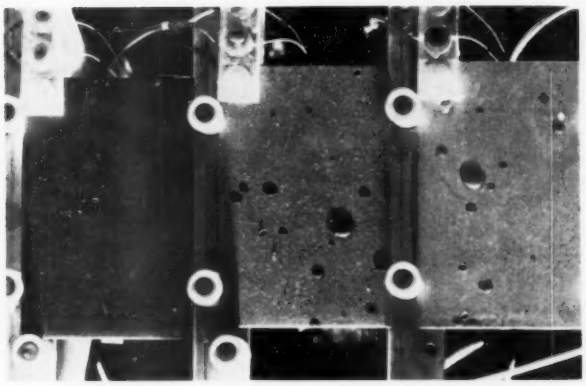
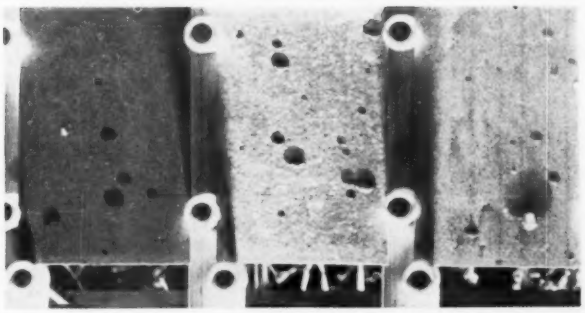


Fig. 3.—Time sequence showing dew forming on the moisture-sensing element.



(1) Steel, corroded (2) Zinc (3) Stainless steel



(4) Aluminized steel (5) Galvanized steel (6) Copper

Fig. 4.—Rain drops on specimens of different metals.

ing system enabled the recording of the first drop of rain that fell on the element or the onset of dew before any visible moisture was present, that is, corresponding to a relative humidity of about 85 per cent on the surface of the element. Observations were made for about 2 months from August to October.

The conclusions reported here are based on records obtained from about 350 hr of wetness. The photographs are typical.

1. When dew was deposited on clean metallic specimens, it appeared as uniform, evenly distributed droplets which varied in size depending on the nature of the surface. The largest droplets formed on galvanized sheet metal, and these were never greater than about $\frac{1}{8}$ in. in diameter (Fig. 1).

2. Where various thicknesses of zinc specimens were used, all with a grit-blasted surface, the deposit of dew was heavier on the thin specimens, although the average temperatures of these specimens measured during dew formation was higher and would indicate the reverse. Figure 2 shows the series of zinc specimens of different thicknesses as well as two corroded steel specimens. On the corroded steel specimens dew deposited as a film of water tended to

stream off the surface in the form of large droplets leaving streaks as shown on the thin steel specimen. A large dam of water accumulated at the bottom edge of the steel specimens. This streaming of water and dam buildup was not apparent on specimens where dropwise condensation occurred until after the surface had been heated by the sun.

3. Figure 3 shows a series of photographs taken every hour from the time moisture was first sensed until a heavy dew was formed. When the first exposure was made, the panel temperature was estimated to be several degrees above the dew-point temperature of the air. Three hours elapsed from the time moisture was first sensed before any droplets of moisture appeared on the surface. In other cases, dew droplets appeared much earlier. After droplets of a certain size had developed, the process seemed to slow down, and this coincided with the observation that the panel temperature tended to approach the air temperature.

4. When rain fell on the surfaces of clean metal specimens, it remained there as discrete drops of all sizes until an accumulation of drops caused coalescence and streaming. The tendency for the water to remain as drops on the surface persisted. In the case of corroded steel, the drops spread quickly into a film and showed none of the characteristics of drops that appeared on the other specimens. Figure 4 shows this effect.

5. During any period of rainfall, the specimens were exposed to many cycles of variable moisture conditions including: drops of various sizes, streaming water, and partially dried surface showing only dampness and a water dam at the bottom edge. The conditions were so variable, as shown in Fig. 5, that it was difficult to define the physical character of the moisture on the surface or to cite any average condition as representative of the period.

Temperatures of the specimens were recorded during the time of wetness, and the average hourly temperatures were obtained from these results. The average hourly temperatures are given in Table II for the period from August 16 to September 16, when the total hours of wetness was 159, of which 66 per cent was caused by dew.

Two facts are significant: the temperature of the corroded steel was independent of specimen thickness, and the average temperature difference between air and specimen was small—less than a degree. This difference may, in fact, be largely due to the difference in elevation, which was about 1 ft, between the thermocouple in the screen measuring air temperature and the specimens. Geiger (5) has shown that temperature inversion near the ground can easily account for the observed difference.

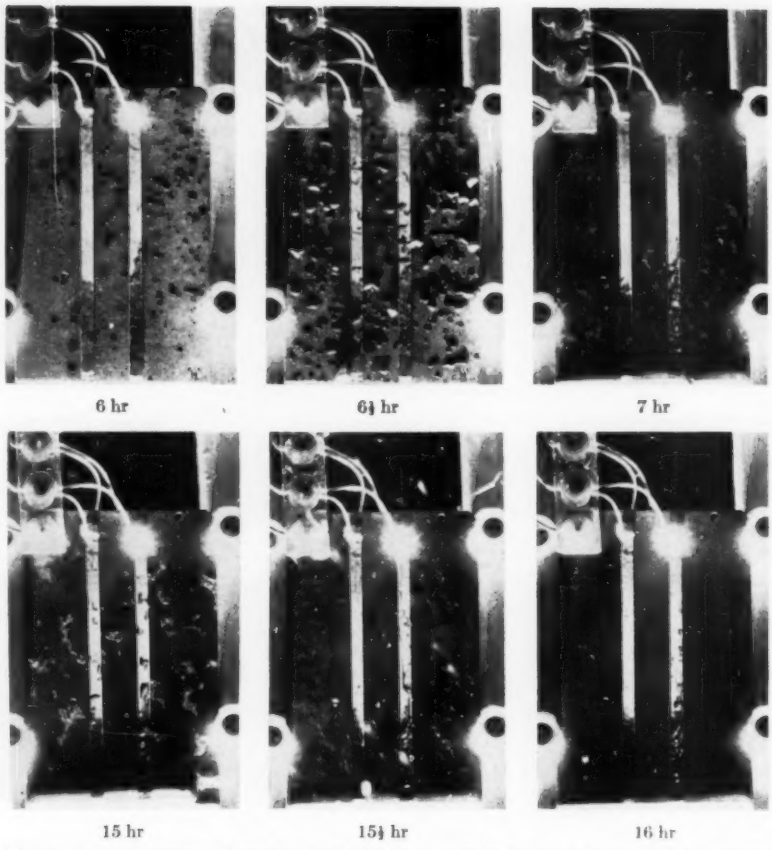


Fig. 5.—Time sequence showing moisture due to rain on moisture-sensing element. (Numbers given represent elapsed time in hours from the start of the rainfall.)

When the specimen was free of water, as it was at nightfall with a clear sky, the temperature difference between the specimen and air was as much as 5 F for the corroded steel and about 2 F for thin clean specimens. This difference between specimens decreased as dew began forming and the temperature of all specimens approached the air temperature. In the morning, when the sun hit the specimens, their temperatures rose above the air temperature for a short time until they became dry. During rainfall, the temperature of the specimens was the same as that of the air. This may explain why the average temperature of the specimen for the time of wetness was very close to the air temperature.

From series II experiments, in which the temperatures of a number of zinc and steel specimens were recorded during the hours of wetness, it was found that the thickness of the metal specimen had very little effect upon the average hourly temperature. The average hourly temperature for the period from September 22 to October 6, representing 198 hr of wetness of which 62 per cent was caused by dew, is given in Table III.

TABLE II.—AVERAGE HOURLY SPECIMEN TEMPERATURES FOR PERIOD FROM AUGUST 16 TO SEPTEMBER 16.[a]

	Corroded Iron Specimens		Steel Specimens	
			Stainless	Galvanized
Thickness, in.	0.1	0.025	0.065	0.035
Temperature, deg Fahr	54.3	54.3	54.4	54.6

[a] Air temperature, 55.1 F.

TABLE III.—AVERAGE HOURLY SPECIMEN TEMPERATURE FOR PERIOD FROM SEPT. 22 TO OCT. 6.[a]

	Steel Specimens, Corroded		Zinc Specimens				
Thickness, in.	0.1	0.025	0.3	0.2	0.1	0.05	0.025
Temperature, deg Fahr	49.5	49.8	49.9	49.9	50.0	49.8	50.2

[a] Air temperature = 50.3 F.

Conclusions

This work has demonstrated that when metal specimens are exposed to the atmosphere and are wetted by rain or dew the nature of the moisture deposit may vary widely from droplets of various sizes to films. The nature of the deposit is influenced not only by the atmospheric conditions and the condition and type of surface but may change through repetitive cycles during any one atmospheric situation. This is particularly the case with rain when even for a steady rain condition a repetitive sequence of drop accumulation followed by drainage may take place, resulting in widely varying amounts of water on the surface. In addition, northern latitudes would involve conditions of snow, hoar frost, and ice, which have not been included in this study. Thus no single steady-state moisture condition can be regarded as typical or representative of atmospheric exposure.

The character of the deposited moisture either from rain or dew on the surface of a corroded steel specimen is very different from that on an uncorroded metal specimen or a metal specimen where the corrosion products present a hard smooth surface, as on copper.

The average temperature of the metal specimens during the time of wetness varied from the air temperature by less than 1 F regardless of type or thickness of the specimen. Larger variations have been observed at the time dew is first forming or at the time the sun begins to shine on the specimens, but these conditions are transitory and tend to cancel one another when averages are considered.

Acknowledgments:

The author is grateful to H. F. Slade and S. E. Dods for their invaluable help in setting up the instrumentation and collecting the results. This is a contribution from the Division of Building Research, National Research Council, Canada, and is published with the approval of the Director of the Division.

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Compatibility Between Bitumens—Exudation Versus Insudation

By G. L. OLIENSIS

Experience with ASTM Method of Test for Contact Compatibility Between Asphaltic Materials (D 1370)[1] has demonstrated that while freedom from incompatibility in that test may correctly be assumed from the absence of an "oily ring" when the saturant and coating are derived from the same asphalt flux, it cannot necessarily be so assumed when the saturant and coating are made from asphalt fluxes of different viscosities or asphalt fluxes derived from different sources.

To judge compatibility correctly in the latter cases, Method D 1370 should be amplified to provide for reporting not only the width of the ring, if any, that forms around the drop of saturant but also the degree of spread of the drop itself upon the layer of talced coating as compared with its spread on a neutral surface such as a talced layer of clean smooth tin. Where the absence of an oily ring around the drop of saturant is accompanied by a noticeably lesser degree of spread of that drop on the talced coating than on the talced tin, an incompatibility of the reverse type is indicated.

A method is outlined in this paper whereby that reverse incompatibility may be corrected by blending the saturant with varying increments of an asphalt of the opposite type of incompatibility until the two trends are balanced and the neutral point of compatibility is reached in which the behavior of the drop of modified saturant on the talced coating substantially duplicates its behavior on the talced tin.

Section 2 of Method D 1370 reads: "A small drop of molten saturant is placed on the freshly talced surface of the coating, and compatibility is judged by the degree to which an oily ring develops in the tale surrounding the drop."

At the time this method was being investigated by Subcommittee XIV of ASTM Committee D-8 on Bituminous Materials for Roofing, Waterproofing and Related Building or Industrial Uses it was pointed out that there was some danger that the term "compatibility," which in that section had been knowingly used in an arbitrarily restricted sense, might be interpreted by

[1] 1958 Book of ASTM Standards, Part 4, p. 927.

G. L. OLIENSIS was graduated from the University of Pennsylvania in 1907, with a major in chemistry and arts and sciences. After some years with The Barber Asphalt Co., he became director of research, in 1945, for the Lloyd A. Fry Roofing Co., Summit, Ill. He has had extensive laboratory and engineering experience in asphalt refining practice, bituminous paving, waterproofing, ready-roofing and built-up roofing, and asphalt paints and protective products. He has done much original research on the micelle structure and mutual compatibilities of bitumens. He is the originator of the Oliensis Spot Test, widely used in the asphalt paving industry, and of the Exudation Test, equally widely used in the asphalt roofing industry. In 1949, he published a book "Exudation and Allied Reactions Between Bitumens," exploring new fields in compatibility reactions between bitumens, to which the present paper serves as a supplement.

those unfamiliar with the actual limitations of that test procedure as indicating that compatibility was assured in *every* case where no oily ring surrounded the drop, and thus prove seriously misleading. Most members of the subcommittee felt, however, that no such misinterpretation was likely among manufacturers of roofing or among asphalt refining personnel, because the general practice in the industry is to use the same flux for both the saturant and coating, in which case the ASTM method as written would be a sufficient guarantee of compatibility.

No trouble was in fact experienced with the ASTM method until, through a change in roofing practice on the Pacific Coast during 1959, an attempt was made to use asphalt coating from Venezuelan flux in combination with an air-blown saturant from California flux. When this combination was tested by ASTM Method D 1370, no sign of an oily ring appeared, and the combination was therefore thought by some to be free of any type of incompatibility.

However, the behavior of the drop of air-blown California saturant on the Venezuelan coating did differ from that of a normal saturant on a normal coating in one respect: instead of the spherical globule of saturant flattening out to form a round and only slightly raised disk on the surface of the coating, as is usually the case, the drop of the air-blown California saturant (though having substantially the same penetration and softening point as the usual saturant) failed to flatten out as it normally would on the California coating. It remained substantially spherical or hemispherical throughout the three-day test, forming an unusually steep contact angle fairly close to 90 deg with the coating layer and showing but little tendency to spread out.

Exudation Versus Insudation

It is generally known that when two bitumens, asphalt saturant A and asphalt coating B, are placed in contact with each other in a solid or semisolid state, their reaction one to the other may be neutral, in which case the consistency of each will remain unchanged, thus justifying their being considered "compatible" with each other. Or one of two contrasting reactions of an abnormal incompatible type may take place: (1) saturant A may tend to grow softer and coating B harder, or (2) saturant A may tend to grow harder and coating B softer.

In case (1), the drop of saturant A will tend to spread out more than it would ordinarily and develop an "oily ring" around its periphery. This reaction has been termed by the author "exudation," or "incompatibility of the exudative type," to signify that some of the softer bodies of the B coating have "exuded" from B and migrated to A, thus softening the A and hardening the B; and the strength of that reaction is roughly proportional to the width of the ring that is formed in Method D 1370. There is no doubt, therefore, that Method D 1370 is satisfactorily effective for detecting incompatibility of the exudative type.

In case (2), however, the drop of saturant A, instead of spreading out wider in that test than it would normally, spreads out noticeably less than is normal (or it may remain spherical or hemispherical with practically no spread at all), and no ring whatever develops. This reaction, the very converse of that in case (1), has been termed "insudation," or "incompatibility of the insudative type." It signifies that some of the softer bodies of saturant A have become adsorbed or absorbed by the coating B, whereby the saturant becomes hardened and the coating becomes softened at the interface. Since in case (2) this type of abnormal change in consistency is not revealed by any telltale ring around the periphery of the drop of saturant when tested by Method D 1370, that method is manifestly incapable of detecting incompatibility of the insudative type.

However, since incompatibility of the insudative type does result in a softening of the coating, and this in turn is very likely to result in serious sticking in bundles of asphalt shingles and even in rolls of asphalt roofing, and may also result in serious sliding and other complications during weather exposure, it is important to guard just as carefully against insudation reactions as against exudation reactions.

A number of tests to detect insudation have in fact been developed and appear in the literature.[2] Unfortunately those test methods sometimes require weeks for completion and considerable care in technique, as well as judgment and experience in interpreting the results. The author now proposes a more rapid and less complicated procedure to help in detecting and measuring the degree of insudation. This procedure is in fact basically only an amplification of the one described in Method D 1370. It is based essentially on the principle that exudation effects, or ring formation around a drop of a given saturant, can be decreased or completely eliminated, either by increasing the degree of air-blowing that the saturant is subjected to, or by blending it with other asphalts from the same source that have already been air-blown, or with asphalts from other asphalts that are inherently of a type strongly enough resistant to ring formation as to be insudative in reaction.

Conversely, it should be self-evident that in the case of a saturant that not only does not develop a ring but shows a decided resistance to a normal spread in Method D 1370, correction should be possible by simply reversing any of the procedures just referred to—that is, by using a saturant that is less highly blown or blending it with steadily larger proportions of the unblown (or steam- or vacuum-type) residues from the same parent flux, or with steadily larger proportions of other asphalts that by themselves do develop a wide ring in Method D 1370. Thereby a point will be reached where rings do begin to form around the modified saturant; and the exact degree of air-blowing, or the exact proportion of the unblown or ring-forming asphalt that must be added to reach that point of neutrality and the normal degree of spread, can be definitely determined, with consequent reduction or complete elimination of incompatibility.

Proposed Amplification of Method D 1370 to Detect and Correct for the Insudative Type of Incompatibility

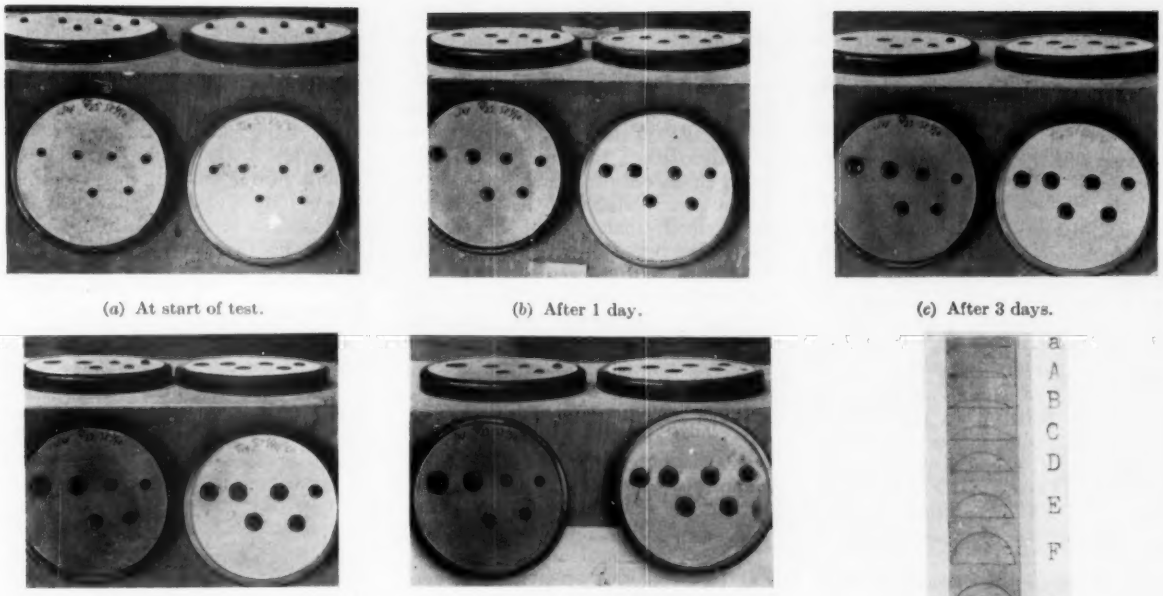
To illustrate how the above trends can be used to verify the presence of insudation when the normal spread of the drop of saturant does not occur, and, if insudation is detected, to determine what steam-vacuum product from the same source would counteract that condition and what proportion of the latter would be required for that purpose, we describe below the procedure followed in the case of the air-blown California saturant that was being considered for use with the air-blown Venezuelan coating.

As previously stated, it had been observed that when testing a drop of the air-blown California saturant on the Venezuelan coating by Method D 1370, no oily ring formed around the saturant, and also the latter failed to spread out and persistently retained its semiglobular shape even after 6 and 9 days in the oven at 115 F.

The first step was to determine whether a steam-vacuum California residual of about the same penetration range would develop a contrasting behavior by spreading strongly and developing a wide ring. This turned out to be the case.

The next step was to prepare a blend of the air-blown and steam-vacuum California coatings in various proportions and test them by Method D 1370, along with the straight steam-vacuum and the straight air-blown product, to determine what proportion of the two would provide substantial reduction or complete elimination of the ring. Why complete elimination of the exu-

[2] G. L. Oliensis, *Exudation and Allied Reactions Between Bitumens*, Forest Publishing Co., Forest Park, Ill. (1949).



(*a*) At start of test. (*b*) After 1 day. (*c*) After 3 days.

(*d*) After 6 days. (*e*) After 9 days.

Fig. 1.—Behavior in exudation test of drops of asphalt saturants on talced coating (at left in each figure) and on talced tin (at right in each figure.) Specimens are arranged according to specimen number from left to right on each tin (specimens 1, 2, 4, and 6 on upper row and 3 and 5 on lower row).

Fig. 2.—Successively larger segments of complete circle.

dation ring may not always be necessary or advisable in such cases will now be explained.

The softening-hardening action occurs primarily at the interface between two asphalts and works outward from that interface only very slowly. For this reason, a layer of talc is applied on the coating layer, so that the capillarity provided by its extremely fine grains will encourage the softened bodies resulting from contact incompatibility to migrate outward beyond the periphery of the drop so as to be exposed to view. It follows that any bitumen of a soft enough consistency, or of sufficiently low surface tension, would similarly be encouraged to flow beyond its original periphery by a thin layer of fine talc and develop a so-called oily ring, even if that soft bitumen were not in contact with another bitumen and therefore no incompatibility were involved. Hence, in such a test some way must also be found to establish not only what the normal spread of the saturant actually is but also whether and to what extent an exudation-like ring will form around it on a talced surface of a nonbituminous substance.

It is therefore necessary to supplement the series of tests just outlined with a blank series of the same blends on some neutral surface in which the factor of incompatibility is completely absent. For that purpose the author uses a flat, thin, smooth, metal plate (the top flat surface of the lid of a tin ointment box is satisfactory). This tin is, of course, first thoroughly cleaned, by dissolving or burning off any oily or lacquer layer on it, rubbing it clean and smooth with fine emery paper or steel wool, and washing with cleanser. This surface is dusted with talc in exactly the same way and to the same extent as is specified for the surface of the asphalt coating layer. The same drops of saturant are then placed on it as on the talced asphalt, and both the talced asphalt-coated tin and the talced plain tin are placed side by side in the oven at the standard temperature. A piece of unsaturated 48-lb roofing felt is placed on the oven shelf under both tins as an extra precaution against undue heat transmission between the metal shelf and the drops of saturant. It is important to avoid the least jarring of

TABLE I.—SATURANTS TESTED.

Specimen	No. 1	No. 2	No. 3	No. 4	No. 5	No. 6
Steam-vacuum California residual, per cent	100	70	50	33	25	0
Straight air-blown California saturant, per cent	0	30	50	67	75	100
Penetration at 77 F, 100 g, 5 sec, mm	53	85	90	92	81	72
Softening point, deg Fahr	117	110	109	112	116	124

TABLE II.—WIDTH OF RING AND CURVATURE OF DROPS ON TALCED COATING AND ON TALCED TIN.

Specimen Number	1		2		3		4		5		6	
	Width, mm	Curvature	Width, mm	Curvature	Width, mm	Curvature	Width, mm	Curvature	Width, mm	Curvature	Width, mm	Curvature
On Talced Coating												
At start	0	H	0	H	0	H	0	H	0	H	0	H
After 1 day	0.35	A/a	0.10	A	0	B	0	C	0	D	0	G/F
After 2 days	0.75	A/a	0.25	A/a	HL[a]	B/A	0	C	0	D	0	F
After 3 days	0.95	a	0.35	a	HL[a]	A/a	0	C	0	D	0	F
After 6 days	1.5	a	0.35	a	0	A	0	B	0	D	0	F
After 9 days	1.75	a	0.35	a	0	A	0	B	0	D	0	F
On Talced Tin												
At start	0	H	0	H	0	H	0	H	0	H	0	H
After 1 day	HL[a]	A/a	HL[a]	A/a	HL[a]	A/a	0	B/A	0	B	0	D/C
After 2 days	HL[a]	A/a	HL[a]	A/a	HL[a]	A/a	HL[a]	A/a	HL[a]	A	0	C
After 3 days	0.25	a	0.30	a	0.20	a	HL[a]	a	0.1	a	0	C/B
After 6 days	0.35	a	0.35	a	0.35	a	0.25	a	0.30	a	0	A
After 9 days	...[b]	a	...[b]	a	...[b]	a	...[b]	a	...[b]	a	...[b]	A

[a] HL denotes hairline, too fine to measure.
[b] Width of ring on talced tin after 9 days impossible to measure because tin was jarred accidentally.

the talced tin, since the talc layer on the bare tin can be much more readily displaced than on the asphalt coating layer, thus rendering inaccurate any reading of the ring width.

Detailed Illustration of Amplified Procedure

In accordance with the foregoing testing plan, a drop of each of six tentatively selected California saturants (Nos. 1 to 6) was placed on a tin covered with the talced Venezuelan coating, and a drop of the same six saturants was placed on the talced tin forming the "blank." These six specimens were arranged on both tins in the order of their specimen number from left to right, specimens 1, 2, 4, and 6 on the upper row of the tin and 3 and 5 on the lower (Fig. 1). Their composition, penetration, and softening point are shown in Table I.

The coating used on the main tin was a straight Venezuelan flux blown back to a penetration of 15 mm and a softening point of 237 F.

The two tins were kept side by side in the oven at 115 F and withdrawn at the end of 1, 2, 6, and 9 days only long enough to be photographed and to permit measuring the width of the rings around the drops and estimating the degree of curvature of the vertical cross-section of each drop at its center.

To help estimate this curvature, a chart was made consisting of a circle whose circumference was divided into six equal parts. Each of these divisions was bisected to obtain 12 equal arcs, *A* to *I*. Arc *A* was again bisected to obtain an arc equal to $\frac{1}{24}$ of a circle. A chord was drawn from the beginning of *A* to the end of the $\frac{1}{24}$ arc and to the end of each of the first nine arcs *A* to *I* inclusive, thus obtaining 10 successively larger segments of a complete circle. Each of the 10 segments was then redrawn separately, one beneath the other, all reduced or enlarged to the same chord length and designated *a*, *A*, *B*, *C* . . . *I*, as shown in Fig. 2. By bringing the eye to the level of the drops on the tins and comparing the front elevation of the drops with each of the 10 segments on the chart, the degree of curvature can be closely estimated and can be recorded by the letter designation of the nearest segment, or by a combination of two successive letters when the cross-section of the drop is about midway between two successive segments.

Table II shows, for each of the six drops of saturant on both the talced coating and on the talced tin, the width of the "oily ring" in millimeters, followed on the right by the letter indicating the degree of curvature of the drop, at the start of the test and after 1, 2, 3, 6, and 9 days in the oven at 115 F.

Figure 1 shows top and side views of the same two tins each with the drops of all the 6 specimens on its surface, at the start of the test and after 1, 3, 6, and 9 days in the oven. The tin on the left is always the one covered with asphalt coating, the one on the right being the talced plain tin. A glance at the successive stages of the test shows fairly clearly that while at first all the 6 drops on both tins were of practically equal diameter and were nearly spherical, the degree of spread of the drops on the talced coating was practically nil for specimen 6 (the straight air-blown California saturant) and was successively greater for the drops to the left, reaching a maximum for specimen 1 (straight steam-vacuum California residual). Similarly, from both the photographs and Table II it is seen that no oily ring at all formed around the last three specimens, Nos. 4 to 6, but a "hairline" developed around No. 3, a ring 0.35 mm wide around No. 2, and an extremely wide ring around No. 1.

On the talced plain tin the behavior of the drops differed from that on the talced coating in two important respects: (1) the degree of spread or flattening of the drops was substantially the same for all six specimens regardless of the increased content of air-blown California saturant, whereas on the talced coating it was sharply reduced by such increments; and (2) while steam-vacuum California residuals of above 110 F softening point happen to be one of the rare types that do develop a ring even on plain talced tin, it will be noted that the width of the ring is always very small, not exceeding 0.35 mm at 6 days, and, like the degree of spread of the drop, is not affected by large increments of the air-blown asphalt to anything like the extent the same drops are on the talced coating tin. A still clearer view of these contrasts between the 6 drops' behavior on the two tins can be obtained from a study of the slightly over-size photograph of the 6-day test in Fig. 2.

Evaluation of Test Data

Judging from the width of the ring alone, on the talced coating, one would naturally conclude that saturant specimen No. 3 (the left one in the lower row), containing 50 per cent of the steam-vacuum California asphalt, which in the first few days of the test had developed on the talced coating a very narrow ring (only a hairline that after a few days had completely disappeared), represented the blend having true compatibility. However, it is also noteworthy that that drop had a somewhat smaller spread than the same specimen had on the talced tin; therefore it was open to question whether in spite of its substantial admixture of exudative steam-vacuum asphalt it was still not veering slightly toward insudation.

In contrast, the behavior of specimen No. 2 on the talced coating was almost exactly like that of its counterpart on the plain talced tin, both in respect to the width of ring and the degree of spread; so one might be equally justified in concluding that specimen No. 2

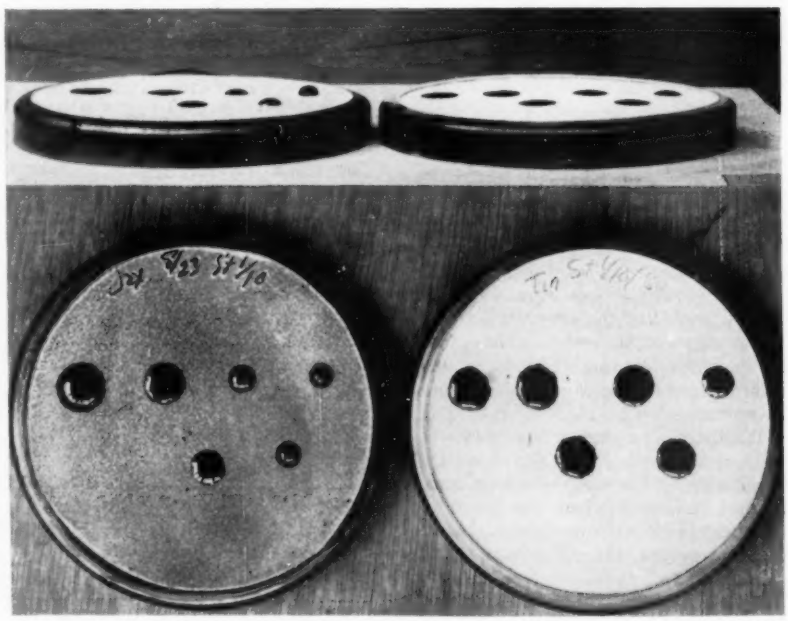


Fig. 3.—Enlargement of Fig. 1 (*d*).

represented the point of true compatibility.

Under those circumstances the wisest decision is to select, tentatively, the midpoint between the two, namely, a blend containing approximately 60 per cent of the steam-vacuum asphalt as the proper combination to use with the California coating.

One should bear in mind that absolute compatibility does not necessarily have to be ensured between a saturant and coating to obtain freedom from undesirable softening-hardening reactions in roofing. This is aptly illustrated by the fact that to ensure absolute compatibility between saturant and coating, a single material should theoretically be used for both, as has indeed been occasionally done in roofing and shingle manufacture. But long experience has proved that if the same flux is air-blown for saturant to a softening point some 75 to 100 F lower than the coating, and even though incompatibility of at least a certain degree should therefore theoretically be expected, nevertheless, the exudation ring usually does disappear at that point and practical compatibility therefore does result for that saturant, as well as for all saturants of higher softening point from the same flux up to the softening point of the coating itself.

Similarly there must be an analogous range of practical neutrality, on the opposite side of the border, between absolute compatibility and a harmful incompatibility of the insudative type. Therefore, in those admittedly rare instances where the steam-vacuum saturant does happen to have a low enough surface tension to develop a ring even on the plain talced tin, the point of practical neutrality may be considered, at least tentatively, to be halfway between that where the exudative ring has just become eliminated, and the point where, with a minimum increase in the content of the exudative ring-forming steam-vacuum asphalt, the degree of spread of the drop and the width of the ring just become equal on both tins. The determination, therefore, of that tentative midpoint in cases like the above is as much as we can at present expect from the quick quantitative method here outlined for determining the presence and the degree of insudation as well as the means for counteracting it.

Should the operator wish to establish more accurately the point of absolute compatibility, he can refer to the chapters on the more elaborate insudation tests in the book previously cited.[2] However, should the operator have insufficient experience to essay those more complicated tests and still wish to check in some simpler way the findings obtained from the rapid test outlined in this paper, an eminently practical test that the author would suggest for that purpose is the following:

Where insudation to any degree has developed in asphalt ready-prepared roll roofing or shingles, with the consequent softening of the coating, it will of course manifest itself with the lapse of time in a steadily increasing tendency of the coating to slide in the standard Underwriters' slide test at 175 F. Consequently, should insudation be suspected, a number of 2- by 6-in. strips of freshly manufactured asphalt shingles should be subjected to that test for 1, 2, or 3 days or until a slight but measurable degree of slide is observed in the coating. The same shingles should then be set aside, preferably in a warm room to accelerate incompatibility reactions. After a month, additional strips should be cut from the same shingles and again subjected to the same slide test and for the same length of time to note whether the sliding is appreciably greater than it was previously. If the operator is still in doubt, the test should be repeated on fresh strips from the same shingle a month or two later. If by then no appreciable increase in slide is noted, insudation can be considered nonsignificant. The author has never found any such increase in sliding tendencies wherever the proper blend of steam-vacuum and air-blown components necessary to eliminate symptoms of insudation has been determined as outlined in this paper.

Conclusion

When a saturant is used that is made from fluxes of a different consistency or from a different source than the coating, and it is noted that in the ASTM Method D 1370 the drop of saturant, in addition to developing no trace of a ring, also shows definite resistance to spread, a simple method is outlined in this paper for quickly determining whether insudation has actually developed, and if so, how the saturant may be modified to correct for the insudation and bring the saturant back to substantial compatibility with the coating.

A Quick Thermal Conductivity Test on Insulating Materials

By R. H. NORRIS and (Mrs.) NANCY D. FITZROY

STEADY-STATE measurements of the thermal conductivity for thermal insulations have been obtained by Lang[1] in as little as 20 min for two 1.5-in. thick slabs of fibrous-glass insulating material. These results have been viewed with some scepticism since no theoretical justification has been available.

The analysis given here shows that the method of Lang has merit subject

NOTE—DISCUSSION OF THIS PAPER IS INVITED, either for publication or for the attention of the author or authors. Address all communications to ASTM Headquarters, 1916 Race St., Philadelphia 3, Pa.

[1] D. L. Lang, "A Quick Thermal Conductivity Test on Insulating Materials," ASTM BULLETIN, No. 216, Sept., 1956, pp. 58–60.

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to certain considerations, namely, homogeneity of specimen, accuracy of location of the heat meter at the centerline of the specimen, neglect of the heat meter temperature differential, and neglect of the response time of the heat meter itself.

Analysis

The object of this analysis is to establish the time required for the temperature gradient at the centerline of a slab to reach 95 per cent of the steady-state value when the slab has been suddenly subjected to a "hot" temperature at one face and a "cold" temperature at the other face. The temperature gradient represents the reading of a heat-flow meter.

The effect of the heat-meter temperature differential and its response time have been neglected in this analysis.

The transient temperature distribution in a slab of thickness, L, with uniform initial temperature, t_0, and suddenly applied temperature, t_f, at one surface ($x = L$), and the other surface ($x = 0$) maintained at t_0, can be expressed as follows [2]

$$\left(\frac{t - t_0}{t_f - t_0}\right) = \sum_{n=0}^{\infty} \times \left(\operatorname{erfc} \frac{(2n+1) - (x/L)}{2\sqrt{\frac{\alpha\tau}{L^2}}} - \operatorname{erfc} \frac{(2n+1) + (x/L)}{2\sqrt{\frac{\alpha\tau}{L^2}}}\right) \quad (1)$$

Figure 1 gives a curve representing this equation for $x/L = 0.5$, that is, at the midpoint.

The derivative of Eq 1, the variation of the temperature gradient with time (representing the reading of a heat flow meter), is:

$$\frac{\partial}{\partial(x/L)}\left(\frac{t - t_0}{t_f - t_0}\right) = \frac{1}{\sqrt{\pi\alpha\tau/L^2}} \sum_{n=0}^{\infty} e^{-Y^2} - e^{-X^2} \quad (2)$$

where:

$$X = \frac{(2n+1) - (x/L)}{2\sqrt{\alpha\tau/L^2}}$$

$$Y = \frac{(2n+1) + (x/L)}{2\sqrt{\alpha\tau/L^2}}$$

Equation 2 is plotted in Fig. 2 for $x/L = 0.5$ (the midpoint). Note that the temperature gradient at $x/L = 0.5$ reaches 95 per cent of its final rise much sooner (namely, at $\alpha\tau/L^2 = 0.1$) than the temperature itself (at $x/L = 0.5$, which requires $\alpha\tau/L^2$ of 0.32). This is the virtue of the Lang technique.

[2] H. S. Carslaw and J. C. Jaeger, "Conduction of Heat in Solids," 2nd edition, p. 310 (Eq. 6), Oxford University Press, (1959).

Symbols

- c = specific heat of the insulation, Btu per lb per deg Fahr,
- k = thermal conductivity of the insulation, Btu ft per hr sq ft deg Fahr,
- L = thickness of insulation, ft,
- n = number of the term in the summation,
- t = temperature, deg Fahr,
- t_0 = initial temperature of insulation, also temperature of surface at $x = 0$ for $\tau > 0$, deg Fahr,
- t_f = temperature of surface at $x = L$ for $\tau > 0$, deg Fahr,
- x = distance, ft,
- α = thermal diffusivity $= k/(c\rho)$, sq ft per hr,
- ρ = density, lb per cu ft, and
- τ = time, hr.

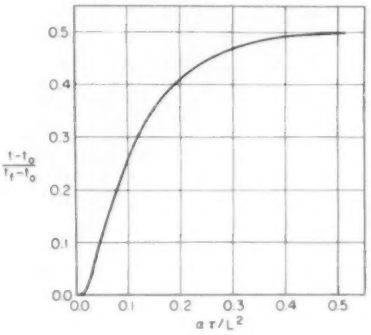


Fig. 1.—Transient temperature distribution.

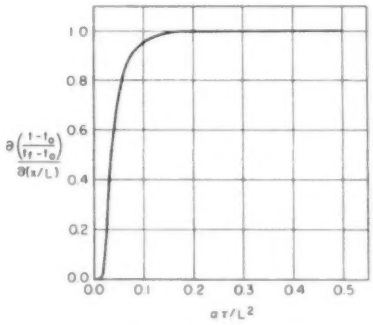


Fig. 2.—Variation of the temperature gradient with time.

Limitations

The homogeneity of the specimen is one important limitation of this analysis, that is, the thermal conductivity, density, and specific heat are assumed to be uniform throughout the specimen. The analysis would not, therfore, be applicable to gas-filled insulations where diffusion in the region near one or both surfaces would cause nonuniformities in properties. Some comments on the effect of nonuniformity of properties are given in the next section.

The accuracy of the location of the heat-flow meter at the midpoint of the specimen may greatly affect the results. The magnitude of this effect will be greatest when the specimen is initially at a temperature different from both the hot- and cold-plate temperature.

It can be seen that when the specimen is initially at a temperature different from both the hot- and cold-plate temperatures (as in the case of insulation just removed from an oven), the solution can be obtained by superposition of two solutions, namely:

(1) both surfaces of a specimen at an initial temperature t_i are suddenly subjected to the same temperature, t_c, and hence the slope at the midpoint is always zero (Fig. 3); and

(2) the case where one surface is suddenly subjected to a different temperature, t_h, the other surface remaining at temperature t_c and the specimen initially at t_c throughout (Fig. 4):

Placement of the meter at a location other than the midpoint, for example, at BB in Fig. 4, will delay the "steady-state" reading of the slope, that is, $\alpha\tau/L^2$ will much exceed 0.1 before the slope

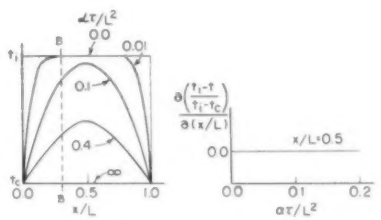


Fig. 3.—Results obtained when *both* surfaces of a specimen are subjected suddenly to a step function of temperature; the specimen initially at uniform temperature throughout.

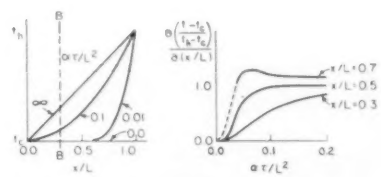


Fig. 4.—Results obtained when *one* surface is suddenly subjected to a step function of temperature, the other surface remaining at the initial temperature; the specimen initially at uniform temperature throughout.

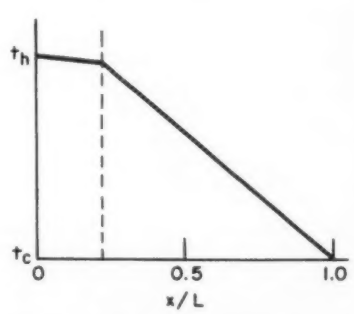


Fig. 5.—Effect of nonuniform thermal conductivity on symmetry.

gets close to 1.0. Note that at x/L = 0.7, an "overshoot" occurs during which an erroneous steady-state reading could be obtained.

Effect of Nonuniformity of Properties

Should nonuniformity of the thermal conductivity exist in the insulation, for example, as is likely to occur in practice when air diffuses into *one* side of a refrigerant-filled foam-slab insulation, the other side being protected from diffusion by a steel wall, the time to reach a steady-state heat-meter reading will be delayed because of the lack of symmetry (Fig. 5). (The explanation of this delay is similar to that given above for location of the heat meter at a location other than the midpoint of the specimen.) A "mean" value of thermal conductivity will result.

If air diffuses into *both* sides of the refrigerant-filled foam, the steady-state prediction of Fig. 2 remains valid, however, a "mean" value of the thermal conductivity of the specimen is obtained. The variation of thermal conductivity with depth of penetration of the diffusion cannot be measured.

Effect of Neglect of Heat Meter

For two 1-in. thick specimens of 5 lb per cu ft fibrous-glass insulation, Lang's Fig. 2 measured 95 per cent of the steady-state meter reading at 10 min. Calculation using Fig. 2, which neglects heat-meter temperature differential and response time, yields 9 min.

Conclusions

1. This analysis indicates that with a meter of negligible response time and temperature differential compared to the specimen located at X/L = 0.5, 95 per cent of the steady-state value of the thermal conductivity of the specimen (as derived from the steady-state temperature gradient read by a heat-flow meter) is reached when $\alpha\tau/L^2$ = 0.1. This corresponds to 20 min for a a specimen consisting of two 1½-in. slabs of fibrous glass with a density of 6 lb per cu ft and k = 0.020 Btu ft per hr sq ft deg Fahr, for example. It is noteworthy that the actual temperature of the specimen at the midpoint has reached only 52 per cent of the steady-state value at that time.

2. The time to reach 95 per cent of the steady-state thermal conductivity will be increased if there is serious lack of symmetry resulting from either nonhomogeneities in the specimen (for example, when air diffuses into one side of refrigerant-filled foam slab), or from location of the heat meter at a point other than the midpoint of the specimen.

3. The initial level of the temperature (uniform) of the specimen before test has no effect on time to reach a steady-state measurement if the heat-flow meter is at x/L = 0.5.

4. For proof of the adequacy of measurements to be made on an insulation system, it is suggested that one test be continued for much longer than the time for $\alpha\tau/L^2$ = 0.1, for example, to $\alpha\tau/L^2$ = 1.0.

Discussion of Article on a Plan for the Self-Qualification of Laboratories[1]

By H. F. Monaghan[2]

WE HAVE READ Dr. McPherson's article with considerable interest. Dr. McPherson's thesis runs so close to lines of thought here in Australia that it seems the necessity for rating of laboratories may be one which needs world-wide consideration.

In Australia the desirability of rating of laboratories appears to have first come under consideration during the early 1930's. No positive action on the matter was taken until 1940, when the very dramatic demands on our defense services testing laboratories by the Australia war effort required decentralization of testing work. This was achieved by the establishment, under government control, of a scheme of approval of laboratories operated by government departments, universities, and some manufacturers to carry out certain testing work with defined limitations on the range of work and the accuracy to be reported.

The scheme worked so well under war-time pressure that it was later felt that a similar scheme could have many advantages for both defense purposes and normal civilian, industrial, and commercial use. It was further considered that the scheme would be more flexible, more generally acceptable, and in all ways more useful if it could be operated on a voluntary basis, without government intervention but not necessarily without government assistance. The result was the establishment in 1947 of the National Association of Testing Authorities (NATA).

Today, NATA is an association of the proprietors of testing laboratories. Its members are consultants, manufacturers, universities, colleges, government departments, and government instrumentalities. In fact, any person or organization who operates a testing laboratory which can be shown to meet a number of fundamental requirements is eligible to join the association. Members' laboratories are registered by the association after assessment designed to ensure compliance with the three basis criteria postulated by Dr. McPherson. Before a laboratory can be registered it must be shown that:

1. The qualifications and experience of the officer in charge of the laboratory, and any other officers having technical supervisory responsibilities, are adequate for the work performed, and there is in the laboratory staff a reasonable balance between adequately qualified and experienced operators and trainees or technicians.

2. The laboratory equipment and facilities are adequate for the work being performed.

3. All equipment has, at a sufficiently recent date, been calibrated in terms of the Commonwealth Standards of Measurement.

A fourth requirement, which was not mentioned by Dr. McPherson, but which can scarcely be overlooked in any assessment of the competence of a testing laboratory, is that the laboratory administration must be completely effective.

NATA works in eight fields of testing: metrology, mechanical testing, electrical testing, photometry and optics, heat and temperature measurement, industrial radiography and crack detection, chemical testing, and biological testing. A laboratory may be registered in any one or more of these fields for the performance of specific classes of test. For each field of testing the association has established a small committee of nationally recognized technical experts. These committees direct assessment of laboratories, make recommendations to the council of the association which will enable the council to grant registration, and supervise continuance of compliance with criteria by registered laboratories. Each committee is supported by groups of assessors who, in a voluntary capacity, assess each laboratory submitted for

[1] A. T. McPherson, "Plan for the Self-Qualification of Laboratories," ASTM BULLETIN, No. 246, May, 1960.

[2] Registrar, National Association of Testing Authorities, Sydney, N.S.W., Australia.

registration and re-assess registered laboratories at appropriate intervals.

The association is controlled by a council, elected triennially, consisting of representatives of the members of the association, of the Commonwealth and state governments, of the professional institutions, the Standards Association of Australia, and the Associated Chamber of Manufactures of Australia. The council thus represents the interests of members of the association, their principal clients or customers, and others concerned with professional or industrial aspects of laboratory operation. A small central secretariat is responsible for the day-to-day operation of the association's affairs.

The cost of the association's operations is on the order of £20,000 (near enough to $45,000) a year. Of this, approximately 80 per cent is contributed in the form of direct grants by the Commonwealth and state governments, who recognize in the association's work the advantages of accreditation of laboratories and the concomitant improvement in the general level of testing work throughout Australia. The remainder of the association's funds come from annual membership subscriptions. No fees are accepted for assessment of laboratories or advice provided by the association when any unsatisfactory situation is brought to light during an assessment.

Registration of laboratories is a purely voluntary affair. The process commences with submission of an application for registration for the performance of specified classes of test. The application is accompanied—or may be followed—by information required to enable adequate briefing of the assessors who will subsequently visit the laboratory. The laboratory is normally visited by two assessors, but a larger group may be required if the laboratory concerned is undertaking an exceptionally wide range of work. The assessors follow a pattern of examination carefully designed to permit full appraisal of the laboratory's compliance with criteria for registration. They discuss with the officer-in-charge and other appropriate officers of the laboratory all details of the laboratory's organization and administration. They examine techniques used, seek demonstrations of techniques where it is necessary, set up trial situations for solution by the laboratory staff, and arrange check tests on sample instruments or materials, or arrange check analyses of reference samples.

The main purpose of assessment is, of course, to achieve registration of the laboratory. If, however, any departures from criteria for registration are noted, the laboratory is given detailed information on the discrepancies together with advice on the most appropriate methods of improvement.

The advantages of assessment are thus manyfold—the laboratory management, as well as the management of the controlling authority, receives the advantage of objective appraisal of its organization, advice is provided on any defect in the laboratory's organization or operation, the laboratory staff receives the advantage of interchange of experience with specialist assessors, and so on. Registration of the laboratory gives it a status that is beneficial at once to its management, its staff, and its clients.

Continuance of registration is dependent on continued compliance with requirements for registration. All members undertake this continued compliance and at the same time undertake to advise the association whenever any change, likely to have any effect whatsoever on the validity of registration, occurs within their laboratories. Registered laboratories are reassessed at reasonably frequent intervals to ensure that adherence to their undertakings has not been overlooked and to ensure that there has not been any undetected drift in the standard of competence of the laboratory.

There must, in any scheme of this type, be some obvious advantages and equally logically some obvious disadvantages. Perhaps I can list some of these and make some comments on each.

First the disadvantages:

1. While the association is an independent organization, it depends to a very considerable extent on government finance. The governments concerned could therefore call the tune if their interests became involved. However, the association has now been in operation for 13 years—admittedly 13 years of rapidly improving economy in Australia—but no government has given any indication of any endeavour to influence the management of the association in any way whatsoever.

2. The association depends on the work of a large number of voluntary supporters as its councillors, members of technical committees, and assessors. This situation is, however, by no means rare. ASTM is one notable example of the success of an organization operated almost entirely by dedicated voluntary workers. NATA, though operating on a much smaller scale, is equally successful.

3. The desire of members to retain registration of their laboratories might result in pressure on the council and technical committees to lower the standard required for registration. This has, however, never occurred. In point of fact, all members of the association have shown, ever since the association was formed, a keen desire to maintain a very sound compromise between highest technical standards and practical considerations. We are completely confident that any laboratory holding NATA registration compares well with a similar laboratory anywhere in the world.

4. The association could become a "closed shop" with earlier members tending to make admission harder for later applicants. Experience has been to the contrary—members are convinced that the membership of the association should increase more rapidly than it does.

On the credit side:

1. Registration gives a laboratory a status independent of the reputation of controlling authority. It is thus possible for a potential client of the laboratory to accept its results with complete confidence whether he knows it personally or not. In a country where the main centers of population are spread as widely as they are in Australia, this is a very distinctive advantage to major purchasing authorities who very often have to order material from a supplier thousands of miles away.

2. Membership in the association is completely voluntary. There is no pressure on any laboratory to join the association. If the organization controlling any particular laboratory sees no advantage in NATA registration, there is no necessity whatsoever for it to become involved in the association's affairs.

3. Acceptability of results reported by NATA-registered laboratories can significantly reduce testing requirements and thereby conserve technical manpower. At the same time, reduction of time in double testing very often permits speed-up of delivery and of payments.

4. Periodical reassessment of the laboratories, and the resultant interchange of technical information between laboratory officers and assessors, brings to light the problems of large and small laboratories. This has enabled the association to make very frequent suggestions designed to improve standard test methods. Most of our contact on this has been with the Standards Association of Australia, but we have also made a number of suggestions on test methods to the British Standards Institute and to ASTM.

5. Advice given to laboratories in the course of, or arising from, assessments has enabled a great number of them to make substantial improvements in their organization or procedure. This has, without doubt, improved the general level of competence of testing laboratories throughout Australia.

The number of testing laboratories in Australia is not known, but it is considered that there may be between

(*Continued on p. 733*)

Metals Application Problems Solved by Joint Action

ASTM-ASME committee has gained the respect of industry through its successful attack on industry-wide problems.

By H. J. Stremba[1]

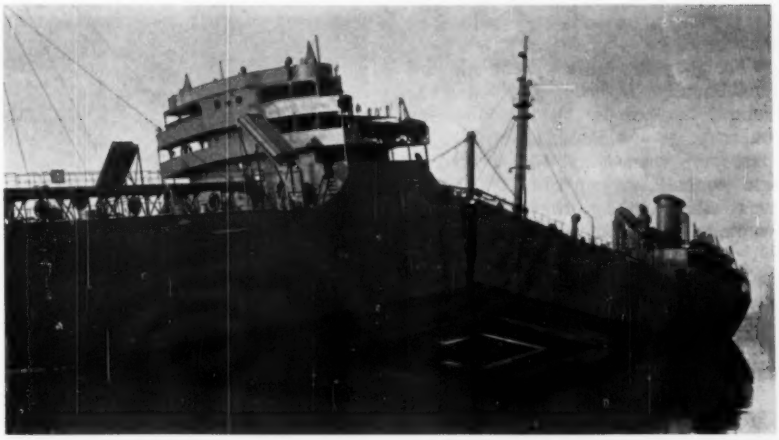
ONE DAY IN 1943, in a power plant at Springdale, Pa., where the Western Pennsylvania Power and Light Co. operates an electric power station, one of the boilers was shut down to remove the steam turbine for servicing. The system cooled and the turbine was removed, when suddenly the 12-in. main steam line from the boiler let go. It was a spectacular failure, the type power plants do not like to dismiss as happenstance or treat as an isolated case. One can imagine what would happen if a failure of this sort became widespread through sweeping the first case under the rug. The power industry, fabricators, suppliers, and even consumer interests wanted to know how this drastic failure could happen. Was there something wrong with the material as produced, or was it affected by fabrication? Years of study and a half million dollars later, industry had the answer.

Expert opinion held that this type of failure was due to graphitization in the material. An industry-wide research program, much of it sponsored by the Edison Electric Inst., confirmed the suspected cause and indicated a solution. What happens is this: In the welded zones of carbon-molybdenum steels, the carbide structure of the pipe material is not stable. Owing to instability when welded, the material solidifies too fast to form a normal structure. When exposed to high temperatures, it tries to revert to equilibrium. Graphite formed from the unstable carbide comes in from surrounding areas and enters the weld-affected zone. The graphite tends to form a continuous line—a section with very low strength. The part fails. The answer here was to provide proper heat treatment of the pipe following the welding operation.

This boiler tube failure was one of many serious industry problems that have been solved by research conducted under the auspices of the ASME-ASTM Joint Committee on Effect of Temperature on the Properties of Metals, J. J. Kanter, Crane Co., chairman. The story of the Joint Committee began 37 years ago when a small group of men became alarmed over the widely dissimilar results being obtained by investigators in elevated-temperature tests of metals. This was hardly surprising, since people were using different types of furnaces for heating the test pieces, different means of measuring temperatures, various periods of time under heat, and different loading speeds. It was impossible to establish reliable strength values for engineering materials at elevated temperatures under approximate operating conditions. For this reason it was urgent that steps be taken to determine the sources of error in the methods being used and to develop methods that would give concordant results.

These men representing ASTM and ASME felt that the time was ripe to organize a committee to undertake this work and to carry out service and laboratory investigations relating to the application and testing of metals at high and low temperatures. Their first step, in 1924, was to organize a symposium on "The Effect of Temperature on the Properties of Metals." This was the kick-off of the ASTM-ASME Joint Committee on Effect of Temperature on the Properties of Metals, and the participants formed the core of its charter membership. Also out of this symposium there evolved a program of cooperative research and standardization upon which the commercial usage of materials at high and low temperatures was to be based.

In its early years most of the committee's research was done in laboratories of cooperating companies; only a small amount of experimental work was done at the expense of the committee. Because of economic conditions in the middle 30's these arrangements were changed, and most investigations were placed with institutions like Battelle Memorial Inst. and the University of Illinois, where the work was done at or below cost. From that time, the committee has stressed this approach to research projects and has tackled some spectacular problems.



Courtesy Ship Structure Committee, NAS-NRC

Brittle failures such as this splitting in two of the tanker *Schenectady*, January, 1943, are of direct concern to the Joint Committee's Low Temperature Panel.

[1] Assistant Technical Secretary, ASTM Staff.

Industry Vote of Confidence

As with almost any group having plenty of enthusiasm and energy, the committee has had its trials. There are its critics who feel the committee has had its place in the sun and should dissolve and let other groups pick up the reins. There are those who question its service and value to industry. By 1958, the disease of criticism had reached the crisis. Committee meetings bristled with proposed cures ranging from mercy death to status quo. This was an anxious time; something had to be done.

Constantly recurring was a burning question that would certainly decide the committee's fate. There were practically no funds in its account, and the question—should a new campaign for funds be undertaken—had to be answered.

The obvious answer, though not unanimously agreed upon, was to submit the case for the committee to industry, for who could better judge the past performance and future need of the committee's work? If industry was willing to contribute funds, the committee had a mandate to continue. Otherwise, it meant dissolution.

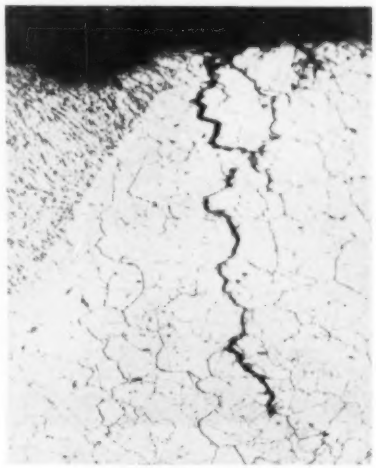
The campaign was kicked off with a goal of $100,000, soon increased to $150,000. With something of its former zest, the committee began to roll. Under the skillful guidance of N. L. Mochel, of Westinghouse Electric Corp., the campaign was highly successful and was officially closed in June, 1961, with 84 companies, institutions, and trade associations contributing a total of $226,000. The committee had its answer.

Case of the Invisible Cracks

Industry's overwhelming vote of confidence had no doubt been strongly influenced by the successful outcome of such cases as that of the Edison Electric Inst. This organization, one of the major contributors to the campaign, had a pressing problem of its own in some of the piping installations in electric power plants throughout the country.

When power plants began operating their equipment at higher temperatures about 12 years ago, they found it necessary to use stronger grades of steel that would hold up in long-time service. The logical choice was to use the 300-series austenitic steel for the superheater tubing and main steam lines. But after years of service, several failures occurred in the main steam lines due to cracking of the tubes in areas adjacent to welds. And in recent years, swelling and rupture failures were detected in some superheater tubes that were first put into service in 1953. Utilities and pressure vessel manufacturers became quite concerned. The Joint Committee was called in and set up two research projects to study the problem. The first covered the main steam lines, and the second took in the superheater tubes. The investigations were carried out at the University of Michigan under contract with the committee.

It should be pointed out that some of the austenitic stainless steels were developed primarily for corrosion resistance, and that heat treatments used to produce differences in grain size may also introduce other structural alterations that could exert a great influence on high-temperature characteristics. Material specifications did not specify grain size for some of these steels and permitted considerable variations in chemistry, manufacturing, and heat treatment. The specifications had no requirement for high-temperature strength, yet these tubes were being used at temperatures up to 1250 F.



Photomicrograph of typical crack in type 347 austenitic steel pipe found adjacent to weld after service.

Two methods for correcting the failures were tried. One was to replace the material. The other was to reheat treat the tubing when swelling was found.

To date, the major result of the project on superheater tubes is the development of a new grade of AISI type 321 steel, which is now included in ASTM Specification A 213 as type 321H. Eventually, other specifications may include these grades. This new material specifies definite heat treatment, a controlled carbon content, and closer limits on titanium. No tubes made of this steel so far have failed.

From its investigations, which lasted several years, the committee learned that minute cracks were formed in the main line tubes during welding, but were so elusive in some cases that they became visible only after heating and cooling cycles in service. The present status of this investigation indicates that the use of AISI type 347 steel as presently specified should be avoided for heavy-section pressurized parts for high-temperature power piping. Although this research may be concluded with no definite solution, most installations now call for type 316 steel in place of type 347.

More High-Temperature Data Needed

The committee's activities are as long as its name, and this case history illustrates only a small segment of its scope. The real meat of its service is the development of standard test methods and recommended practices for determining the effect of temperature on the properties of metals. Just recently, chairman J. J. Kanter pointed out that "the most urgent practical undertaking confronting the committee is to provide the methods of test and data correlations which will serve the writing of better specifications for high-temperature material."

High-temperature tests are not mandatory to any great extent in materials specifications. It has been stated that adequate tests are costly and time-consuming and cause delay in material procurement. This is becoming less true as more data become available which correlate long- and short-time rupture properties. The Data and Publications Panel of the Joint Committee has collected and compiled volumes of data on the physical and mechanical properties of metals and alloys. Its published material (graphs, data sheets, and descriptive material) runs to 28 volumes, totaling more than 2500 pages. This information is accepted by industry and code-writing bodies as being the best data available on which engineering designs can be based. The committee has modernized its data surveys so that the information is now transferred to punched cards that are available in three groups: light alloys, iron and steel, and superalloys and refractory alloys.

The data panel is currently evaluating data on the properties of materials to assist the ASME Boiler and Pressure Vessel Code Committee in determining their suitability for use, and to establish working stresses. Existing and future data will be compiled to establish whether they fall within various limits of appropriate materials specifications.

In Tune with Industry Needs

Through its members, numbering more than a hundred, the Joint Committee has built-in antennas tuned in to technological changes in many industries, and through the years it has changed its structure accordingly.

The aircraft industry, for one, has experienced a technological evolution in recent years that stresses space flight and missiles. This required a different approach to research and development. In making the adjustment, the former Aircraft Panel was reorganized in 1959 with a new scope and under a new name, "Panel on Structural Materials for Airframes and Missiles."

In its new role, this panel has been doing research of direct benefit to the aerospace industry. Its members represent materials suppliers, aircraft companies, universities, and government agencies. Its programs and activities are developed through task groups which presently cover studies on: (1) compression properties of sheet materials, (2) refractory metals, (3) low-temperature properties of high-strength materials for airframes and missiles, and (4) problems dealing with the Mach-3 transport aircraft (a program undertaken at the request of representatives of NASA).

The Gas Turbine Panel, another of the eight panels serving the committee, recently reorganized its membership and scope to cover problems in aircraft gas turbines. At the same time the panel continues to follow its original work with the industrial gas turbine.

Test Development

The committee developed its first test methods in 1933 and has kept them up-to-date with periodic revisions. These methods cover short-time tension and creep-rupture procedures. Recently, the Test Methods Panel developed methods for performing short-time creep tests under conditions of rapid heating and loading at elevated temperatures. These were specifically designed to determine properties of materials used in aircraft and missiles. Methods for conducting compression, bearing, and shear tests and tests to determine dynamic and static elastic modulus are under development.

MEMBERS OF JOINT COMMITTEE

(Left to right) Howard Cross, Battelle Memorial Inst., now serving his 14th year as secretary; Henry M. Soldan, Public Service Electric and Gas Co., who spearheaded the research on the steam power projects; Norman L. Mochel, Westinghouse Electric Corp., past chairman; and Jerome J. Kanter, Crane Co., present chairman. Not shown is George V. Smith, Cornell University, vice-chairman of the committee.

Just completed was a project to provide creep-rupture test specimens for calibrating creep machines. Using a common material, the properties of which are precisely documented, there should be much greater reproducibility of results from various laboratories conducting creep tests.

Research

The Applied Research Panel is another example of revitalization to keep abreast of changing times. This panel, which once considered only problems of general research, as it was named, is now working on specific projects designed to get information on rupture tests of longer than 25,000 hours. Most of the data are of European origin. Another project under way will cover the role of surface and material defects in thermal fatigue.

This past June the Low Temperature Panel held a comprehensive symposium on the Evaluation of Metallic Materials in Design for Low-Temperature Service.

The Petroleum and Chemical Panel finds its most pressing problem at present to be the lack of stress-rupture data in the temperature range of 1800 to 2000 F on materials suitable for the manufacture of ethylene. It recently formulated a program designed to provide the necessary information on several selected alloys in this temperature range, with the work to be done on a contract basis.

The work of the Joint Committee sets a pattern for successful solution of industry-wide materials problems by joint action. Cooperation is effective not only between two great technical societies—ASME and ASTM—but also among the many industry members of the committee and the numerous organizations that have contributed funds for research sponsored by the Joint Committee. What is difficult or impossible for one company to do alone, joint action can achieve.

Self-Qualification of Laboratories

(Continued from page 730)

2000 and 3000. Many of these, of course, are engaged in aspects of testing work in which membership of NATA would not be an advantage. At present, 342 laboratories hold NATA registration. It is expected that within a fairly short time most of the significant laboratories that can make effective use of registration will be registered.

It is felt that our experience closely parallels the ideas so clearly postulated by Dr. McPherson. There is certainly a need for accreditation of competent laboratories, although we rather doubt that effective rating can be achieved on a do-it-yourself basis. Unfortunately, the necessity is not always recognized, and so demand and necessity do not match.

COMMENT BY A. T. MCPHERSON[3]

Australia has pioneered in achieving a practical and satisfactory solution of an important problem that we in the United States have only begun to talk about.

The situation in Australia differs from that here in the United States in two important respects. In the first place, NATA receives 80 per cent of its support from the Australian Government, whereas such a subsidy would not be possible in the United States. Furthermore, it is doubtful that representatives of either our Federal Government or our state governments would be permitted by legal counsel to participate in the governing body of an organization which would pass upon the qualifications of laboratories when a satisfactory rating might be a necessary prerequisite for a laboratory to engage in work for either a government agency or a government contractor.

In most, if not all, other respects, the NATA procedures and operations could be adapted to use in the United States, and they would certainly warrant careful consideration and study.

[3] Associate Director, National Bureau of Standards, Washington, D. C.

Society Affairs

ASTM To Sponsor Symposium on Cleaning and Materials Processing for Electronics and Space Apparatus

THE SOCIETY will hold a three-day Symposium on Cleaning and Materials Processing for Electronics and Space Apparatus in conjunction with the Fourth Pacific Area National Meeting, to be held at the Statler-Hilton Hotel, Los Angeles, Calif., Sept. 30–Oct. 5, 1962.

It is now generally recognized that the reliability, uniformity, and reproducibility of electron devices, precision machinery, and hardware for space exploration are controlled in large measure by minute traces of extraneous materials. Therefore, the examination of materials and processing procedures for constructing devices and hardware in the virtual absence of trace contaminants is highly desirable and, in many cases, an economic necessity.

This symposium, to be sponsored by Committee F-1 on Materials for Electron Tubes and Semiconductor Devices, will bring up to date the materials and processing problems in electronic device fabrication which were the subjects of the 1958 Symposium on Cleaning of Electron Tube Components and Materials and the 1961 Symposium on Materials and Electron Device Processing. It is expected that this symposium will deal extensively with materials and processing problems common to electronic devices and their fabrication and the chemistry and physics of their operation, as well as similar problems encountered in production of space apparatus. These subjects fall into four broad categories:

1. Examination of device materials.
2. Treatment and examination of specific components.
3. Processing facilities, such as chemical agents, processing liquids and ambients, including dust and lint control.
4. Device experience with ultraclean conditions.

Since many contamination and processing techniques and materials problems are common to other industries, such as pharmaceuticals, optics, aircraft, and precision machinery, many of the topics will be of paramount interest and importance to people from these areas.

Papers Invited

Individuals desiring to present a paper should submit the title and a 200-word abstract to D. E. Koontz, Bell Telephone Laboratories, Inc., Murray Hill, N. J., no later than January 1, 1962.

Highlights of Research Committee Meeting

THE ADMINISTRATIVE Committee on Research, charged with the responsibility of promoting the research aspects of the Society's work, met at the Annual Meeting to discuss what steps the Society might take to: (1) aid the dissemination of information on materials properties, (2) encourage informal research sessions at committee meetings, (3) encourage or sponsor state-of-the-art publications in materials fields, and (4) unify the very large field of deterioration of materials.

Properties Data

The committee reviewed a recent publication of the ASTM-ASME Joint Committee on the Effect of Temperature on the Properties of Metals on the subject "Physical Properties of Metals and Alloys from Cryogenic to Elevated Temperatures" (*STP 296*). This report, which contains largely thermophysical data, including thermal conductivity, specific heat, and other nonmechanical properties, represents a departure from most projects sponsored by the committee, which generally covers mechanical properties. The committee feels that similar projects in fields other than metals should be encouraged, and accordingly a task group was formed to explore the needs for collection and dissemination of data on materials other than metals.

Informal Research Sessions

The Research Committee has been concerned for some time about how the Society might encourage participation by younger people, particularly those who are doing research in the field of materials. The committee considered sponsorship of informal sessions at national meetings of the Society at which younger scientists and engineers would be invited to present their research results informally without any requirement for publication. It was felt that such sessions might very properly be sponsored by ASTM technical committees, and the committees are encouraged to set aside a time at their meetings for such informal research sessions, inviting younger people especially to attend and present their research as well as to participate in committee activities.

Review on Reviews

The Research Committee has also been concerned about the increasing need for state-of-the-art publications and reviews to serve both the new graduate who needs to become oriented in some field of materials and also the experienced scientist or engineer who wishes to gain knowledge about a field other than that of his specialty. In discussing how this problem might best be approached, the committee members agreed that the first step was to find out what is now being published of this nature. Accordingly, the committee has instructed the staff to approach several libraries and information centers to establish a bibliography of materials reviews. Such a bibliography might then be the basis for a review of reviews for publication by the Society.

Deterioration of Materials

The ASTM Board of Directors is exploring the need for a broad approach in the Society on the subject of deterioration of materials due to environmental effects. The extensive activities in the Society relating to corrosion are well known, but other committees are concerned with deterioration due to such things as microbiological attack and various radiation effects, particularly in connection with nonmetals. The Research Committee will cooperate with several other committees of the Society, including the Administrative Committee on Simulated Service Testing, the Advisory Committee on Corrosion, and Committee E-1 on Methods of Testing, to explore this subject and submit recommendations.

Research Grants

The committee considered several proposals for grants-in-aid for group research in materials which had been referred to it by the Administrative Committee on Fellowships and Grants-in-Aid. It approved continuing a project at the University of Minnesota under Prof. B. J. Lazan to study damping properties of materials and structures. Support is in the amount of $1000.

Subsequently by correspondence, the committee approved two more $1000 research grants—to Prof. James R. Sims, Rice University to support an investigation of vibrating wire strain gages and to Prof. Ralph G. Crum, Carnegie Tech to support research to correlate recent advances in experiment and theory of dynamic loadings so that impact data may be more useful in rational stress design.

ASTM MEETINGS

Date	Group	Place
Oct. 1	Committee D-3 on Gaseous Fuels	Dallas, Tex. (Hotel Adolphus)
Oct. 2–3	Committee E-17 on Skid Resistance	Knoxville, Tenn. (University of Tennessee)
Oct. 3–5	Committee D-10 on Packaging	Ottawa, Ont. (Forest Products Laboratory)
Oct. 4–5	Committee C-8 on Refractories	Bedford Springs, Pa.
Oct. 5–6	Committee C-3 on Chemical-Resistant Mortars	Lake Placid, N. Y. (Marcy Hotel)
Oct. 6	Central New York District	Messine, N. Y.
Oct. 9–11	Committee D-27 on Electrical Insulating Liquids and Gases	Virginia Beach, Va. (Hotel Cavalier)
Oct. 9–12	Committee B-5 on Copper and Copper Alloys, Cast and Wrought	Washington, D. C. (Willard)
Oct. 11–12	Committee C-14 on Glass and Glass Products	Bedford Springs, Pa.
Oct. 16–18	Committee D-9 on Electrical Insulating Materials	Montreal, P.Q. (Sheraton-Mt. Royal)
Oct. 17	Northern Plains District	Minneapolis, Minn.
Oct. 17–18	Committee C-19 on Structural Sandwich Constructions	Buffalo, N. Y. (Statler)
Oct. 17–20	Committee D-13 on Textile Materials	New York City (Sheraton-Atlantic)
Oct. 17–20	Committee D-20 on Plastics	Montreal, P.Q. (Sheraton-Mt. Royal)
Oct. 18	Central Plains District	Kansas City, Mo.
Oct. 19	Mississippi Valley District	St. Louis, Mo. (Engineers' Club)
Oct. 23–24	Committee D-14 on Adhesives	Buffalo, N. Y. (Statler)
Oct. 24–25	Committee B-9 on Metal Powders and Metal Powder Products	Detroit, Mich.
Oct. 24–25	Committee C-25 on Ceramics for Electronics	San Francisco, Calif. (Jack Tar Hotel)
Oct. 26–27	Committee B-4 on Metallic Materials for Thermostats and for Electrical Resistance, Heating, and Contacts	Chicago, Ill.
Oct. 26–27	Committee C-20 on Acoustical Materials	Chicago, Ill. (University Club)
Oct. 30	Philadelphia District	Swarthmore, Pa. (Swarthmore College)
Oct. 30–31	Committee B-1 on Electrical Conductors	Washington, D. C. (Sheraton-Park)
Oct. 13 (tentative)	Pittsburgh District	Pittsburgh, Pa.
	1962	
Feb. 5–9	**Committee Week**	**Dallas, Tex. (Statler-Hilton)**
June 24–29	**Annual Meeting**	**New York, N. Y. (Statler)**
Sept. 30–Oct. 5	**Pacific Area Meeting**	**Los Angeles, Calif. (Statler-Hilton)**
	1963	
Feb. 4–8	**Committee Week**	**Montreal, P.Q. (Queen Elizabeth)**
June 23–28	**Annual Meeting**	**Atlantic City, N. J. (Chalfonte-Haddon Hall)**

1962 Award of Merit Committee

THE 1962 AWARD of Merit Committee, appointed by the Board of Directors, includes F. C. Burk and E. A. Thomas, serving with holdover members F. G. Tatnall, chairman, and Harold Allen. A. A. Bates will represent the Board of Directors on the committee. In accordance with Rules Governing the Award of Merit (p. 774, 1960 ASTM Year Book), all suggestions for 1962 Awards must be in the hands of the Executive Secretary of the Society for consideration by the committee not later than February 1, 1962.

Offers of Papers for 1962

THE ADMINISTRATIVE Committee on Papers and Publications will meet early in February to consider the papers to be published by the Society in 1962 and to develop the programs for the Annual Meeting (New York, June 24–29) and the Fourth Pacific Area National Meeting (Los Angeles, Sept. 30–Oct. 5).

All those who wish to offer papers for presentation at either or both of these meetings and publication by the Society should send these offers to Headquarters *not later than January 10, 1962.* (See also invitation for papers for Committee F-1 symposium, p. 734.)

All offers should be accompanied by a summary that makes clear the intended scope of the paper and indicates features of the work that will, in the author's opinion, justify its publication and inclusion on the program.

Forms for supplying this information are available from ASTM Headquarters.

TECHNICAL COMMITTEE NOTES

Annual Report of JCUMWE

THE JOINT COMMITTEE on Uniformity of Methods of Water Examination, made up of representatives of 12 technical organizations engaged in the development and publication of methods of water examination, was organized 5 years ago to review methods published by member organizations to obtain uniformity in sampling, testing, reporting test data, and terminology, and to provide for information exchange.

Methods review is by panels of outstanding specialists. An approved panel report becomes a Preliminary Recommendation, which is then referred to member organizations. After review and study there, the recommendation is issued by JCUMWE as an Official Recommendation.

Official Recommendations have been approved for reporting of results, total hardness, iron, organic nitrogen, grease and oily matter, solids, and manganese. Preliminary Recommendations under review by member organizations are for sulfate, uniformity of reagents, acidity, and alkalinity.

Metals for Thermostats and Electrical Resistance, Heating, and Contacts (B-4)

HOT SPOTS in wire-wound resistors can cause malfunction in expensive electronic equipment which, in turn, controls devices such as elevators, aircraft, and rockets, not to mention the home TV set. Committee B-4 is taking steps to reduce the likelihood of such hot spots by developing tests for measuring resistance linearity of resistance wire. If linearity of resistance versus length is known and is controlled within certain limits, it is possible not only to eliminate hot spots but also to determine what length of wire is needed to give a certain resistance.

The committee is also developing standards for iron-chromium-aluminum alloys for electrical heating. The aluminum, present up to $4\frac{1}{2}$ per cent, provides oxidation resistance at high temperatures and enables production of low-cost heating alloys.

The thermostat metals group is continuing to develop and improve tests for flexivity, thermal emissivity and conductivity, and corrosion and deflection rates of thermostat bimetals. The thermal properties are of special interest since they govern a thermostat's ability to respond to ambient temperature. The group has prepared a bibliography on thermostat bimetals to be published soon by the Society.

The electrical contacts subcommittee is studying erosion of contacts under heavy arcing conditions and has now devised a procedure that shows reasonable agreement when used in different laboratories. The reliability of contacts is under continuous study in the committee, which is presently evaluating the effect of humidity on surety of make of contacts that have been cleaned by different techniques. Further evaluation of the effect of environment on contacts is going forward at ASTM test sites at Newark, N. J., and Kure Beach, N. C. Funds are being solicited to expand this program.

Committee B-4, in cooperation with the American Institute of Electrical Engineers, the National Association of Relay Manufacturers, and the University of Maine, is sponsoring an International Conference on Electrical Contacts to be held at the University of Maine, November 14–16, 1961.

Natural Building Stones (C-18)

THE RECENT efforts of Committee C-18 on Natural Building Stones to develop specifications for the most commonly used types of natural building stone have achieved a very significant effect throughout the industry. This industry, although one of the oldest, has now realized the need for coordinated research to gather information on which to base proper quality specifications. The Tentative Specification for Structural Granite (C 422) is the first attempt to establish a specification in this field based on physical properties. At a recent meeting of the committee it was reported that industry members are planning a very intensive program of research to provide information on which to base better specifications. Durability was emphasized as one subject needing research so that a method of test can be developed for measuring this property.

The work group on limestone has conducted a survey of the industry, which included the circulation of a proposed specification. The replies will be reviewed for possible improvement of the specification before presentation to the committee. At the present time, five classifications of limestone are being considered.

Two classifications of marble are being considered in a proposed specification. Presentation of a proposed specification for sandstone is being deferred pending a further review of a need for a saturation test as well as for classification of what are commonly known as soft and hard sandstones.

Additional problems have arisen in connection with standards for slate owing to new uses now being made of this material. Test methods may be needed to define such factors as hardness, abrasion, texture, chemical composition, and natural markings.

The importance of definitions is being emphasized inasmuch as proper specifications cannot be written without them. New terminology is coming into use in connection with veneer and curtain-wall construction. Definitions of more varieties of stones are needed.

Paint (D-1)

THE PAINT committee has revised and brought up to date a large number of methods for testing drying oils (D 555) and fatty acids (D 1467) used in protective coatings.

When the committee's annual report was presented to the Society, the proposed Tentative Method of Test for Perspiration Resistance of Organic Coatings was referred back to the committee for further study. The committee also withdrew from its report the recommendation for adoption as standard of the Specifications for Raw Linseed Oil (D 234).

The new Subcommittee on Miscellaneous Raw Materials will develop tests and specifications of various types of paint additives. This would include such materials as silicones, sterates, fatty nitrogen compounds, lecithins, and gums, used as rust inhibitors, fungicides, and wetting agents. Two working groups have been established, one on fatty nitrogen compounds and the other on antimicrobial agents. Other working groups will be organized either on the basis of chemistry or function of the material.

Returns from a questionnaire sent to various state highway departments brought valuable information regarding new tests that are needed for traffic paint. The committee decided to begin studies on water immersion, flexibility, night visibility under wet conditions, and infrared absorption analysis.

New theoretical concepts of solvency presented to the Subcommittee on Solvents may lead to a practical and reliable technique for calculating solvent power as well as viscosity reduction power of hydrocarbon oxygenated solvents. The group on chemical intermediates reported good progress in the development of specifications for formaldehyde, acetaldehyde, vinyl acetate, and pentaarythrital.

The Subcommittee on Accelerated Tests for Protective Coatings is developing a method for determining the presence of passivation on galvanized steel surfaces. Such surfaces are difficult to paint. This problem is made more difficult by the many different passivation treatments used in the manufacture of galvanized sheet. Round-robin tests are under way of methods for film breakdown measurements by electrical conductance cells.

A number of new methods for the widely used latex and emulsion paints are being studied. These include scrubability and washability, efflorescence from substrate, package stability, microbiological tests, coalescence, and weathering test of exterior latex paints. Results obtained by six laboratories in a cooperative test to evaluate the resistance of emulsion paints in the container to attack by microorganisms were reviewed. A round-robin program being planned will use sterility as a measure of adequate resistance to deterioration and will use a single spoilage organism as an inoculum in a vehicle of emulsion paint.

Petroleum Products and Lubricants (D-2)

FLAME IONIZATION detectors and capillary gas chromatographs are useful in the quantitative analysis of many petroleum products. For example, aviation gasoline can be analyzed with greater precision by the gas chromatograph than by conventional methods. The advantages of these analytical methods were discussed at a special informal symposium held by Committee D-2 at the 64th Annual Meeting of the Society in June.

Cooperative testing of the Russian method (GOST 63) for determination of tetraethyl lead in gasoline and the ASTM method (D 526) has led to the conclusion that the ASTM method is more suitable for international standardization because it is more precise and applicable to a wider range of gasoline stocks.

New reference fuels will be proposed next year for the cetane engine test method (D 613). The new fuels will be a purer *n*-cetane (100 cetane number) and heptamethyl-nonane (15 cetane number). The latter will replace the current low-cetane-number reference fuel, alphamethylnaphthalene.

Work is under way on the development of new engine test methods for predicting knock characteristics of motor gasoline. This work is aimed toward establishing engine test methods with better precision and significance than the current motor and research methods. Three study groups are active on problems of: (1) improved equipment and instruments, (2) road test data, and (3) fundamentals of knock testing.

The following symposia are in the planning stages:

- Measurement of Vapor Pressure of Lubricants in Reactor Systems, St. Louis, January, 1962.
- Specifications for Liquefied Petroleum Gas Motor Fuel, St. Louis, January, 1962.
- Industrial Application of Hydraulic Fluids, St. Louis, January, 1962.
- Steam Turbine Oils, New York, June, 1962.
- Lubricant Performance in Automotive Equipment, Los Angeles, October, 1962.
- Motor Gasoline, Los Angeles, October, 1962.
- Nuclear Technology and Problems Related to Petroleum Products and Lubricants, Los Angeles, October, 1962, or January, 1963.

Rubber (D-11)

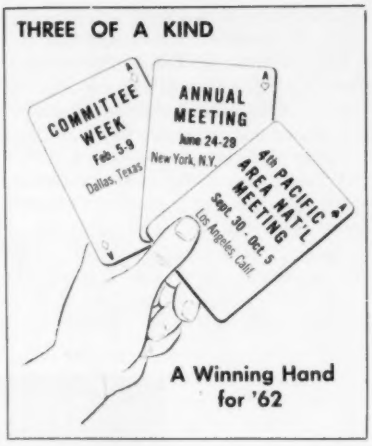
THE PACKINGS Subcommittee has reviewed a new method of test for sealability of gasket materials developed in the Joint SAE-ASTM Technical Committee on Automotive Rubber following extensive cooperative studies by the Joint Committee for the past five years. The method will be submitted to letter ballot of Committee D-11 for publication as tentative.

A new method of test for determining viscosity of rubber latices by the Brookfield apparatus is under development and will replace the capillary method now in use.

The procedure for determining nitrogen in crude natural rubber was withheld from the D-11 Report so that the committee could give further study to this procedure based on the British Standards Inst. Method.

The new method of test for adhesion of vulcanized rubber to single-strand wire was accepted as tentative. The committee is now developing a method of test for adhesion of multiple-strand cord to vulcanized rubber. It appears that the molding process for single-strand wire can also be applied to multiple-strand cord with appropriate modifications for immersion depth. The first set of interlaboratory tests on multiple-wire cord adhesion were discussed and arrangements made for another series of tests to be completed and reviewed at a later meeting.

A new "H-Pull" type test for measuring adhesion of textile cords to vulcanized rubber was approved for letter ballot. This method has been developed in cooperation with Committee D-13 on Textile Materials. The following three methods of testing adhesion of textile cords to rubber are under study: (1) Albertoni Test Method, (2) Goodrich Pop Test Method, (3) Continental "CF" Test Method. Plans are



under consideration for an interlaboratory study of these procedures.

The Subcommittee on Flexible Cellular Materials announced that work is under way on specifications and methods of test for rubberized curled hair. A brochure on this subject submitted to the subcommittee will be reviewed and rewritten.

The Joint SAE-ASTM Technical Committee on Automotive Rubber reported completion of the new Classification System for Elastomeric Materials for Automotive Applications (ASTM D 2000; SAE J 200), which represents a culmination of five years of extensive work. This new classification will be published as tentative after acceptance by the parent societies. It is eventually intended to replace the present Automotive Rubber Specifications (D 735).

The Specifications for Nonmetallic Gasket Materials for General Automotive and Aeronautical Applications (ASTM D 1170; SAE J 90) were also revised, several new grades being added and others deleted. Revisions were also completed in the SAE specifications for fuel and oil hose. A new tentative specification for power steering hose is in preparation, and consideration is being given to a nylon-dacron hydraulic brake hose. Studies are continuing on problems dealing with air-conditioning hose for automobiles.

Textiles (D-13)

COMMITTEE D-13 presented to the Society at the recent Annual Meeting a group of twelve tentative methods of test and one extensive series of definitions for zippers. These test procedures for an important accessory used with textiles were developed in cooperation with the Slide Fastener Assn. and are the result of some five years of extensive study. The zipper methods are being made available in a separate, 44-page publication. They cover such practical tests as colorfastness to laundering, dry cleaning,

light, rubbing or crocking, and perspiration. Resistance to abrasion and durability of finish of zippers to laundering, dry cleaning, and salt fog are also included. Other methods cover measuring procedures, strength tests, and operability of zippers.

A list of commercial moisture regains commonly used for a number of textile fibers (D 1909) was also accepted as tentative. Such moisture regain values are primarily used for determining commercial weight of a fiber that is bought or sold by weight. These regain values are also used for calculated and linear density or yields and in the quantitative analysis of fiber blends as required by the Federal Trade Commission Rules and Regulations issued under the Textile Fiber Products Identification Act.

The specifications for fineness of wool, wool top, and mohair were brought up to date, and standard methods were adopted for determining the diameter of wool and mohair fibers by microprojection. These methods can also be used for allied fibers such as cashmere, alpaca, and camel hair. Two new methods for wool included a test for hydrogen ion for aqueous extracts of wool and a method for rapid estimation of staple length of wool tops. Procedures for yarn severence in woven fabrics and a general procedure for yarn number by the skein method were published as tentative. A newly developed series of infrared spectra for a number of textile fibers will be used in connection with the methods for identification of fibers in textiles (D 276).

The next meeting of Committee D-13

TECHNICAL COMMITTEE OFFICERS

OFFICERS OF COMMITTEE A-10 ON IRON-CHROMIUM, IRON-CHROMIUM-NICKEL AND RELATED ALLOYS

Left to right: G. R. Woodrow, secretary, G. O. Carlson, Inc.; L. L. Wyman, chairman, National Bureau of Standards; M. A. Cordovi, vice-chairman, The International Nickel Co., Inc.; *not present,* Jerome Strauss, honorary chairman.

OFFICERS OF COMMITTEE C-7 ON LIME

Left to right: H. F. Kriege, chairman, Research Foundation, University of Toledo; L. E. Johnson, secretary, The Finishing Lime Association of Ohio; *not present,* E. T. Carlson, vice-chairman, National Bureau of Standards.

OFFICERS OF COMMITTEE D-22 ON METHODS OF ATMOSPHERIC SAMPLING AND ANALYSIS

Left to right: A. T. Rossano, Jr., secretary, California Institute of Technology; J. Cholak, chairman, The Kettering Laboratory, University of Cincinnati; M. D. Thomas, vice-chairman, University of California.

OFFICERS OF COMMITTEE D-27 ON ELECTRICAL INSULATING LIQUIDS AND GASES

Left to right: C. A. Johnson, secretary, Socony-Mobil Oil Co. (retired); H. W. McCulloch, Jr., vice-chairman, Shell Oil Co., Inc.; *not present,* E. R. Thomas, chairman, Consolidated Edison Co. of New York, Inc.; R. M. Frey, membership secretary, Line Materials Industries.

OFFICERS OF COMMITTEE E-2 ON EMISSION SPECTROSCOPY

Left to right: R. E. Michaelis, chairman, National Bureau of Standards; D. W. Henthorn, secretary, Vanadium Corporation of America; *not present,* R. W. Smith, vice-chairman, General Motors Corp.

will be held in New York City on October 17–20, 1961, at the Sheraton-Atlantic Hotel. On Thursday, October 19, the committee will sponsor a Symposium on Statistical Principles and Practical Applications at which the following four papers will be presented:

Basic Statistical Analysis—Norbert L. Enrick, University of Virginia.
Specifying Proper Number of Tests—George M. Bornet, Ontario Research Foundation.
The Interlaboratory Evaluation of Test Methods
Part I: General Principles—J. Mandel, National Bureau of Standards.
Part II: Application to the Tongue-Tear of Woven Fabrics—T. W. Lashof, National Bureau of Standards.

Industrial Chemicals (E-15)

ORGANIC PEROXIDES can be tricky chemicals to handle. They can explode without warning unless handled in a certain way and have been known to cause great damage. Also, the formation of peroxides in extremely small quantities, when certain chemicals are exposed to the air, is often the cause of instability which, if not controlled, can result in significant losses through deterioration. The Task Group on Peroxides of Committee E-15 was instructed to develop standard tests for the whole gamut of peroxides, all the way from traces in chemicals to the 100 per cent organic peroxides. Object: to enable better control of these tricky chemicals.

Development of density-temperature tables for chemicals is showing good progress. Ten such tables for different chemicals have now been developed for ballot of the committee. Standardization of such tables is very much needed to enable agreement on the volume measurement of these chemicals when sold in bulk. The well-known ASTM-IP Petroleum Measurement Tables, which have been adopted internationally through the ISO, have effected significant economies for the petroleum industry. Standard measurement tables may be expected in time to provide similar economies for the chemical industry.

The task group on *n*-butyllithium—a highly reactive polymerization catalyst—got off to a good start by pooling the various methods now used for assay. The newly formed task group will develop both sampling and analytical techniques.

The committee has issued its first standard—Tentative Recommended Practice for Developing Precision Data on ASTM Methods for Analysis and Testing of Industrial Chemicals (E 180). This document includes a glossary of terms, information on planning interlaboratory studies, statistical analysis of collaborative data, information on expressing precision of methods, bias or systematic error, and presentation of data.

Skid Resistance (E-17)

AN IMPORTANT factor in the measurement of skid resistance for traffic surfaces is the characteristics of tires. Committee E-17 recognized this in its organization and established a Subcommittee II-e on Tire Characteristics and Significance. The scope of this subcommittee now reads: "To develop and standardize tires for use in measuring skid resistance of traffic surfaces; to encourage and sponsor research pertaining to the characteristics of such tires which significantly influence their sliding characteristics." At its recent meeting, the subcommittee heard that a pavement test standard tire has now been manufactured and will be available for use in research on skid resistance. The Subcommittee on Winter Driving Hazards of the National Safety Council will use the standard tire in its basic research on tire performance on ice and snow this coming winter. The tire was developed under the auspices of the Technical Advisory Committee of the Tire and Rim Assn.

Plans were made for a field correlation study as the result of a joint meeting of Committee E-17 members, the Highway Research Board Committee on Road Surface Properties, and other agencies. The study will involve various machines to measure surface friction. The Virginia Council of Highway Investigation and Research was considered the logical group to plan and conduct such a study. Subcommittee II-a of Committee E-17 will serve as the advisory committee on this project.

Following the presentation of a paper on the correlation of the British Portable Tester and the Virginia Skid Test Car, a task force was formed, composed of all members who have the British Portable Tester, to study uniformity of results with this type of apparatus.

Sensory Evaluation of Materials and Products (E-18)

COMMITTEE E-18 has been studying a number of tests developed by other committees involving sensory evaluations. It is believed that significant improvements in these methods may result from the use of recognized psychometric techniques. The Subcommittee on Preparation of Recommended Practices has outlined the following six sections which should be included in a recommended practice for sensory testing:

- Environmental conditions of tests.
- Number of observers for several purposes of tests.
- Selection of observers.
- Suprathreshold matching method.
- Dilution threshold method.
- Intensity rating method.

The Subcommittee on Principles of Psychometric Testing is compiling a list of journals and other sources of pertinent information to serve as a guide and source of material for future activities.

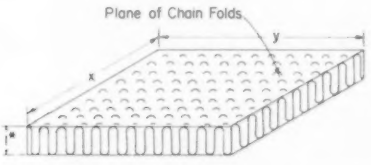
The Subcommittee on Instrumental-Sensory Relationships is also making a literature survey, particularly in the areas of smell, taste, and visual sensory measurement. It is felt that a bibliography is vital to future activity and that a critical review of each subject will provide a basis on which investigators in unrelated fields may exchange information and seek out common problems and solutions. The committee will concern itself both with immediate industry problems and basic long-range research problems which will advance the general knowledge.

COMING MR&S PAPERS

The Scientific Application of Particle Accelerators to Nondestructive Testing—E. A. Burrill, High Voltage Engineering Corp.
Accuracy Problems at Rapid Rates of Mechanical Testing—R. W. Fenn, Jr., and A. A. Moore, The Dow Metal Products Co.
Stress-Relaxation—Some New Test Methods for the Determination of This Mechanical Property Either in Tension or in Compression—G. R. Gohn and A. Fox, Bell Telephone Laboratories, Inc.
Quick and False Set in Portland Cement—W. C. Hansen, Consulting Chemist.
Effects of Elevated Temperatures on Mechanical Properties of the H-7213 Micarta (Astrokon)—S. Y. Lu and W. A. Nash, University of Florida.
Sinusoidal Strain Dynamic Testing of Rubber Products—A. R. Payne, Rubber and Plastics Research Association of Great Britain.
Improved Adiabatic Calorimeter for Concrete—David Pirtz, University of California.
Tensile Impact Testing for Plastics—R. F. Westover, Bell Telephone Laboratories, Inc., and W. C. Warner, The General Tire and Rubber Co.

Polymer Crystals with Folded Chains

THE NATURE of polymer crystals is of considerable interest, since such crystals affect the mechanical, optical, and dielectric properties of these useful materials. As part of a long-range program involving the dielectric properties of polymers, scientists at the National Bureau of Standards are investigating the fundamental characteristics[1] of these materials.



SCHEMATIC DIAGRAM OF LOOP-TYPE POLYETHYLENE CRYSTAL FORMED FROM DILUTE SOLUTION.

In 1958, it was discovered that certain polymers, such as polyethylene, are deposited from dilute solution in the form of flat and very thin crystalline platelets.[2, 3] The surprising feature of these plate-like crystals is that they are built up of *folded* polymer chains. The folds themselves actually form the large upper and lower surfaces of the platelets. The chain axes of the unfolded portions of the polymer molecules are roughly perpendicular to the plane of the chain folds (see cut). This is a vastly different structure from the bundle-like or sheaf-like structure that one might have expected the crystals to exhibit.

A detailed theoretical interpretation of this phenomenon has recently been presented by J. I. Lauritzen and J. D. Hoffman of the Bureau's Dielectrics Section. Their explanation involves nucleation and growth theory. They have demonstrated that in sufficiently dilute solution, the rate of formation of the seeds leading to folded crystals must exceed that of seeds leading to crystals of the bundle-like type.

The growth of each folded nucleus was then considered. It was shown that the thickness (often called the step height, l^*) will not increase rapidly as the platelet becomes larger in the x- and y-directions, thus preserving the thin platelet character of the crystal. This tendency for the step height to maintain itself during the growth process is a result of the fact that a crystal of step height l^* grows much faster than one that is either substantially thicker or thinner. The quantity l^* generally ranges from roughly 100 to 500 Å and increases with temperature of crystallization.

The theoretical study has recently been extended to the case of crystallization in bulk polymers.[4] Results were obtained which strongly suggest that substantially chain-folded crystals (lamellae) exist in bulk polymers, especially in the spherulites. Calculations have recently been made at the Bureau which give information on the smoothness of the chain-folded surfaces of the lamellae and on the details of the melting behavior to be expected for chain-folded crystals.[5]

High-Temperature Behavior

BEHAVIOR OF materials at extremely high temperatures continues to command world-wide interest and research effort. Knowledge gained from research will be applied to advancing space exploration and nuclear and plasma technology, but, perhaps even more far reaching, it will help to satisfy man's curiosity about what happens in nature's power plants—the stars. The concern of the Defense Department has been quoted here before: "Basic studies are recommended to discover the laws of chemistry and physics that prevail in the temperature zone between the melting and decomposition points of the most refractory of known materials and indefinitely high upper limits such as 10,000 or 20,000 K."[6]

Recent Advances in High-Temperature Chemistry of Materials was the subject of a 5-day symposium comprising 90 papers held as a part of the 18th International Congress of Pure and Applied Chemistry, in Montreal, Canada, August 6–12.

Broadly divided into three main sections—Gaseous State, Condensed State, and Thermodynamic Properties—the symposium emphasized new concepts, procedures, and instruments for measuring, describing, and explaining the behavior of materials at high temperatures.

The property of flames as conductors of electricity was the basis for several recent large-scale research efforts described by several speakers. B. Karlobitz of Combustion and Explosives Research, Inc., told the symposium of the development of a new type of high-temperature flame in which the heat content of the combustion products was augmented by a high-voltage discharge through the conducting flame. The temperature of such electrically augmented flames ranges from about 2000 to 5000 K, a range which is technically very important as even the most refractory solid will melt or decompose within this range. The flames can be used to study a great variety of reactions that occur at high temperatures and can be made either oxidizing or reducing, depending on the composition of the combustion products. Extremely high temperatures can also be obtained by means of the plasmajet, which is a stream of gas passed through an electric arc. R. H. Turin of the Warner and Swasey Co. reported research on the measurement of radiation energy given off by a plasmajet. The radiation spectrum of the plasmajet covers a portion of the ultraviolet, as well as visible and infrared, with the amount of radiation depending on the plasmajet temperature and the number of gaseous particles passing through it. Dr. Turin was able to vary the amount of heat radiated by using different kinds of gas.

Progress in magnetohydrodynamics (MHD) was reported by Ian Fells of Sheffield University in England. According to Dr. Fells, possibilities for MHD, which utilizes the principle of electrical conductivity of flames and arcs, are increasingly promising as an efficient means of generating electricity. An MHD generator is not subject to the limitations of present day thermodynamic systems, which are limited in efficiency to about 40 per cent of the available energy in the fuel.

"The first MHD generators were constructed along relatively simple lines," said Dr. Fells. "The high-speed ionized gas stream is produced by what is, in effect, a rocket motor; fuel and oxygen are fed into a high-intensity combustion chamber, and the high-temperature products of combustion, seeded with potassium to improve their conducting properties, are passed through a supersonic nozzle to increase their velocity. . . and then through a strong magnetic field. Current is taken out of the system by means of electrodes set at right angles to the gas stream and the magnetic field, as in Faraday's first experiments."

[1] J. I. Lauritzen, Jr., and J. D. Hoffman, "Theory of Formation of Polymer Crystals with Folded Chains in Dilute Solution," *Journal of Research*, Nat. Bureau Standards, Vol. 64A (Physics and Chemistry), No. 1, p. 73 (1960).

[2] A. Keller and A. O'Connor, *Discussions*, Faraday Society, Vol. 25, p. 114 (1958).

[3] A. Keller, *Philosophical Magazine*, Vol. 2, p. 1171 (1957).

[4] J. D. Hoffman and J. I. Lauritzen, Jr., "Theory of Rate of Lamellar Spherulitic Crystallization in Bulk Polymers," *Journal of Research*, Nat. Bureau Standards, Vol. 65A (Physics and Chemistry), No. 4, p. 297 (1961).

[5] J. D. Hoffman and J. J. Weeks, "The Melting Process and the Equilibrium Melting Temperature of Polychlorotrifluorethylene," (to be published).

[6] "Materials Research for Defense," ASTM BULLETIN, No. 250, Dec., 1960, p. 6.

This type of generator suffers from several disadvantages, Dr. Fells said, among them the high cost of seeding the fuel with potassium, the very high temperatures involved (about 2800 C), and the fact that the generator, in its simple form, produces low-voltage direct current which must be converted to alternating current for general commercial use.

These problems are being solved in various ways, however, according to Dr. Fells. The combustion system, for example, can be tailored to produce a pulsed gas stream which makes possible direct production of alternating current.

"The basic property of the gas stream which is of importance in generator design," he said, "is the gas conductivity, and a fundamental research program is being carried out at Sheffield University and other institutions to examine the basic ion-producing mechanisms occurring in the flames with the intention of encouraging them to produce more ions and thus do away with the necessity of potassium addition. At the same time, more sophisticated methods of generator design are being developed."

Despite the "considerable" problems remaining, Dr. Fells asserted, "there is tremendous scope for ingenuity in devising better and more efficient MHD generators, and if the inventiveness applied to the improvement of turbogenerators during the last 50 years can be channeled into producing new methods of electricity generation, it seems not unreasonable to expect that a practical and efficient MHD generator will be developed."

Standards Conference Set

METHODS WHEREBY companies may apply the philosophy and practices of standardization to reduce production costs and increase profits will be explored at the 12th National Conference on Standards, to be held October 10–12 in Houston, Tex.

At the second session, on Philosophy and Practice of Standardization, ASTM Executive Secretary T. A. Marshall, Jr., will describe the activities and future plans of the newly reorganized Pan American Standards Committee.

Sponsored by the American Standards Assn., the conference will afford industry the opportunity to assess current standards work in terms of immediate and long-range goals, application of standards in reducing costs in many areas, and the financial benefits to the company of standards application. Attendance is open to all organizations and individuals, whether or not they are ASA members. Further information may be obtained from ASA Headquarters, 10 E. 40th St., New York 16, N. Y.

Magnesium Association To Discuss Standards

ONE ENTIRE session of the 17th Annual Convention of the Magnesium Assn., Oct. 16–18, at the Belmont Plaza Hotel in New York City, will be devoted to a panel-in-depth discussion of standards and specifications. Recognizing that there are areas of misunderstanding in customer-supplier relationships, the panel, representing both views, will seek to focus on standards as a safeguard of the interests of both.

To counter a common impression that magnesium is a metal dependent solely upon defense demands, a display of "101 Commercial Applications of Magnesium" will spotlight many unnoted applications in everyday industrial, commercial, and home life.

NEW ASTM PUBLICATIONS

"Specifications?!."

Tenth Gillett Memorial Lecture, by Augustus B. Kinzel. Single copies to members on request. Additional copies to members 80 cents. List price $1.

IN THIS LECTURE, one of our nation's leading research metallurgists presents an agonizing reappraisal of just where standardization stands in this Nuclear-Space Age. Dr. Kinzel pulls no punches. We have, it would appear, a long way to go.

"Specifications—question mark, exclamation point, period," says Dr. Kinzel at the beginning of his lecture. "The question mark pertains to the first part of this lecture: What is the purpose of a specification? What sort of historical evaluation has resulted in the nature of today's specifications? What use is being made of specifications and what abuses are involved?

"The exclamination point pertains to the present astonishingly unsatisfactory state of the art, to the astounding lack of communication and pertinence in many specifications, and to the inexcusable waste due to ignorance of materials, meaning of tests, and lack of understanding of engineering service requirements!

"The period pertains to the end result, Utopian no doubt, when the improvement of specifications and ways and means of keeping them up to date, made possible by really good engineering and reduction of ignorance will put an end to our present dilemma."

Dr. Kinzel maps the path to that Utopia. To stay on that path, he says, we need to:

1. Write specifications for materials that have meaning with respect to the intended service and are precise and mathematical in character.
2. Find some way to provide variance from specifications without undue penalty and some way to specify the degree and nature of variance that is in accord with common sense.
3. Develop the nondestructive testing techniques—mechanical, chemical, etc.—that will assure us that tests verify the relationship of the material tested to that which is actually used.
4. Carry out engineering research in order to gain knowledge, in broad as well as in specific areas, and in this way to make a determined attack on the ignorance that underlies the factor of safety.

There is a wealth of good sense in this lecture. One feels that a periodic re-reading of its message by those who are engaged in producing materials standards for the nation would be beneficial in renewing the outlines of the ultimate goal.

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Research Abroad

By BRUCE W. GONSER[1]

A FEW MONTHS ago I visited some of the research institutes and metallurgical research people in Moscow and Kiev. This was through an exchange visitation of four metallurgists. Although this was my ninth visit to Europe in connection with research, it was the first one that included the U.S.S.R., and in many ways it was the most important for understanding and evaluating research abroad—at least in the metallurgical field.

Our research activity has grown phenomenally in the past 15 years. It has in Europe, too. This is particularly evident in the U.S.S.R., because researchers there started from a much lower base. In fact, almost everything there must be judged in terms of improvement over the immediate postwar conditions rather than by direct present comparison.

One of the first impressions one gets in visiting research laboratories abroad is the much greater proportion of women in the technical staffs than we have. Again, this is most pronounced in the U.S.S.R., not only in chemistry and the biological sciences but in metallurgy and engineering. Opening these fields to women, or, rather, encouraging them to enter, certainly makes available many more skilled researchers. As to quality, the women seem to hold their ground well in research by sheer merit. There are no particular advantages given them that I could see, and they are doing about every type of work for which they are physically capable. In comparing experiences in training women research workers, it is interesting to note how often the statement is made that "They are either very, very good or no good at all." In other words, if a woman is really capable and interested in her job she may easily do better than a man in many research activities, but if the job is merely a side issue and her heart is not in it, she may become merely a pair of skilled hands. Of course, some interesting problems sometimes occur. In an Oslo laboratory the staff on one project was puzzled for a time because some of their delicate electrical equipment went haywire whenever one young lady physicist came near, much to her distress. Once the accompanying radiant cloud of static was traced to nylon somethings, corrective clothing was quickly adopted and the laboratory returned to tranquility.

Making comparisons in the worldwide research field can be treated adequately only in detail and with many qualifications. There are too many exceptions, conditions in each country are too variable, and any individual's observations are too limited to even attempt broad, direct comparisons. What we must all realize, however, is that much really excellent research work is going on in other countries which deserves our utmost respect and attention. Advances into the unknown and "gray" areas there, as well as here, proceed irregularly. One group may get well ahead of the world in one specialized area at the neglect of other areas. In the materials field broadly, and in metals particularly, we are at present not falling behind. This may be cause for pride of accomplishment but not for complacency.

Turning to the U.S.S.R. for more direct comments, I was struck more in visiting research laboratories there by similarities with our own than with differences. Many items of equipment, for example, even though Soviet-made, were very similar to ours. The scattering of German and other imported items, both new and old, were similar. The same new Japanese electron microscopes which we find so useful were noted there. True, the laboratories lacked many of the features of convenience and comfort that we find so desirable in our new laboratories, and crowdedness was evident, but the essentials for research were there and obviously were used. Also lacking were certain specialized new instruments, but one got the impression that alertness was being shown in either obtaining a new instrument rather promptly or devising one of their own make to supply the need.

A complaint among our research people has been the difficulty of keeping up with the technical literature. We are not the only ones; this is a universal wail. The Soviet Union may be very prompt in getting important foreign articles translated, as we try to do also. However, it is one thing to have the article available and another to find the time to read it and utilize it.

Generally, our researches seem to be somewhat more closely followed by industry because so much is done in company laboratories or as company-sponsored research with definite objectives in mind. In the U.S.S.R., results of researches by the national institutes seem to be made available more by publications and symposia than by progress reports. The desire to publish is very strong among researchers there. Having publications, and particularly books, to one's credit adds materially to income and privileges, as well as to prestige. The laboratories are well filled with eager young men and women who have won their jobs competitively. They seem to be capable and have the incentive to continue the present rather high rate of progress. We should expect from them, as well as from our own group of young people, a constantly increasing rate of accomplishment.

One of the items that any American visitor to a research laboratory abroad is likely to notice is the universal use of the metric system (except to some extent in the British Isles). Some of the more common measurements can be converted mentally to inches and pounds, but when tensile strength results in kilograms per square millimeter and impact values in kilogram meters per square centimeter are given, for example, it takes awkward paper and pencil calculations before they become meaningful. Complete conversion to the metric system is something we are going to have to accept eventually, of course.

Among the handicaps to research that we find is the difficulty in getting a pet line of investigation approved by management and getting the money to do it. Again, this is not a unique situation. They have the same troubles, although possibly in a different manner, in Russia, in Switzerland, in Spain. Repeatedly in discussing research problems the comment is made, "We have the same troubles!" Thus, looking at the research picture broadly, the outstanding fact is the similarity of aims, of people, of equipment, and of problems. All of us want to leave the world better than we find it. There is a universal eagerness among researchers to share their knowledge, to be recognized, and to be friendly. An exchange visit to other countries, and particularly to the U.S.S.R., may not affect the world situation profoundly, but it is something. Most troubles come from misunderstandings, and a better knowledge of each other, even in a very small way, is better than no contact at all.

[1] Technical Director, Battelle Memorial Inst., Columbus, Ohio.

LETTERS

Ugh!

¶ The preface article entitled "Needed: More Talk Less Communication" (*MR&S*, June) leads me to believe that you are an advocate of kindergarten level terminology.

It would be interesting to learn the amount of time spent in composing the article, wherein every word is, as you say, of the "short," "clipped," and "curt" variety. I would venture to guess that this required a considerable effort for a man of your status.

Must we regress to The Dark Ages in our form of speech, using a few guttural commands? You say we should speak and write as if we were men of science. Should not, in each case, our writing be tailored to the level of understanding of the particular type of individual addressed? Why do large words even exist, if they are not meant to be used? Is it not because they alone can express precisely what we are trying to say?

While I am completely aware of the fact that writing can easily become stilted through misuse of long words, whose meaning is not understood, I also feel that we should not restrict our terminology to a low, unnatural level.

This letter should provide you with a suitable subject for your next issue, if you care to print it.

G. E. LaPorte
Buffalo, N. Y.

¶ Re: Pledge, page 447, *MR&S*, June, very fine. Would I could do as well.

Harold M. Smith
Chairman, ASTM Committee D-2

¶ Three cheers! Your squib on the first page of June's *MR&S* drives your point home in words that I like too—short words. If you can make that much sense in one page in all that you write—once through—you are right hot with your pen; and you show well what can be said, if you try hard, in words of one speech sound at a time.

My hat is off to you. (I would soon run down.) Keep up your good work!

F. T. Mavis
University of Maryland
College Park, Md.

The Troost Story

¶ The photograph of Gerard Troost on page 470 of the June issue was viewed with considerable skepticism when related to the indicated lifetime dates of 1776–1813. This would have made Troost 37 years old at the time of his death and I have never seen a man 37 or younger look as old as the one in your photograph. Furthermore, he would have lived during the time of Washington, Franklin, and Jefferson, who to my knowledge never had a photograph taken, and yet this excellent portrait apparently was technically possible during those days. Finally, the ruffles and laces used on the clothing of gentlemen of that day (according to most paintings) were far removed from the almost modern suit shown. A quick look into an encyclopedia clarified the situation. The correct lifetime dates were given as 1776–1850.

Melvin R. Meyerson,
Metallurgist,
National Bureau of Standards
Washington, D. C.

¶ On page 470 of the June 1961 issue, there appears a note on Gerard Troost (1776–1813) and a photograph. Is this intended to be a photograph of Troost? Could it be?

Troost died in 1850. This might explain the photograph—or does it?

Capt. A. M. Blamphin, USN (Ret.)
National Academy of Sciences–
National Research Council
Washington, D. C.

[*1813 was, after all, a good year.*—Ed.]

RANDOM SAMPLES

First Isotope-Powered Automatic Weather Station

The world's first isotope-powered, automatic weather station is about to go into operation in the Canadian Arctic.

A dream of meteorologists for many years has been automatic weather observation from strategically located remote areas. Manned stations in such areas present problems of recruiting and supplying a staff. An automatic station, able to function unattended for up to 2 yr, has now been developed through the use of isotope power.

The U. S. Atomic Energy Commission and the U. S. Weather Bureau spearheaded the design and fabrication of equipment to provide reliability consistent with the long life of the isotope, to use a minimum of electrical energy, and to provide accurate weather data in usable form.

The close cooperation maintained between the U. S. Weather Bureau and the Canadian Department of Transport prompted the latter's Meteorological Service to suggest that the station be installed in the Canadian Arctic. It will therefore be located on remote, uninhabited Graham Island in the vicinity of Norwegian Bay, about midway between the Canadian weather stations at Eureka and Resolute.

The station and power source are housed in a cylindrical, insulated container, about 8 ft long. The lower 5 ft will be buried in the permanently frozen ground. An anemometer, thermometer, and barometer will measure wind direction and speed, temperature, and barometric pressure. These readings will be fed into a data processing system and will emerge ready to go directly into the radio transmitter, which will relay them every 3 hr to Resolute and Eureka.

The power source is located in the lower chamber of the housing. Consisting of a strontium-90 heat generator and thermocouples, batteries, and a converter, it uses an insoluble chemical form of strontium-90 securely locked in a corrosion-resistant capsule and shielded by $\frac{3}{4}$ ton of lead. The excess heat from the isotope is used to maintain an interior operating temperature of about 70 F. Heat from the strontium-90 is converted directly into electricity to charge the nickel-cadmium storage battery which powers the radio transmitter. The isotope is capable of producing usable power for over 10 yr. The compound used, strontium titanate, is insoluble and biologically inert, with a melting point so high that it could not be dispersed by the hottest gasoline fire.

Uncle Sam Heavy Supplier of Heavy Water

The sale of 169,500 lb of heavy water to the government of Canada, the largest shipment made by the United States since it began to sell heavy water to other countries in 1955, resulted in a record quarter-year total of 170,625 lb for the period ending March 31, 1961. The combined sales, including 1000 lb to Norway and 125 lb to Australia, at the established price of $28 per lb, amounted to $4,777,500.

Canada purchased the heavy water at a cost of $4,746,000 for use in its natural-uranium-fueled, heavy-water-moderated, power reactor program. Most of the shipment, 159,500 lb, will be used in the 20,000-kw prototype NPD-2 power demonstration reactor which is nearing completion at Rolphton, Ontario. This reactor is a prototype for the 200,000-kw CANDU plant scheduled for completion at Douglas Point on Lake Huron in 1964. The other 10,000 lb were sent to the Atomic Energy of Canada, Ltd., at Chalk River, Ontario, for use in the NRX and NRU reactors.

(*Continued on p. 748*)

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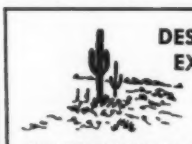

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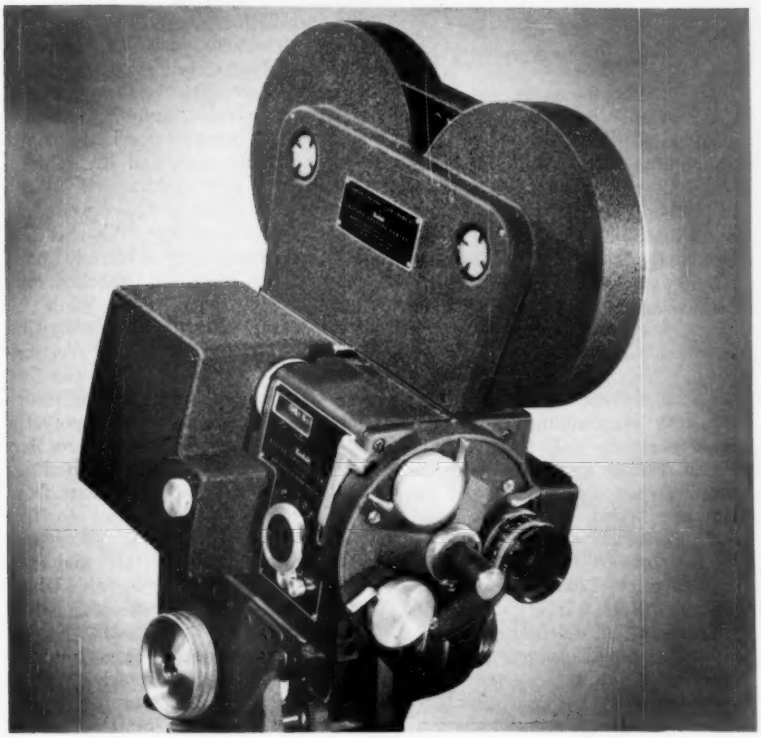
Kodak reports on:

time-lapse at the professional level . . . 70,000,000 pounds per pound . . . the pencil that enrages the mind



Clear, steady movies

This is a professional motion picture camera. It is called the *Kodak Reflex Special Camera (16mm)*. Its price is $1895. (Any amateur who buys it imperils his amateur status, but that's his lookout, not ours.) For a professional camera the price is remarkably low, particularly since it is the latest and most versatile of professional 16mm cameras and everybody knows that the cost of professional equipment in most fields rarely goes in any other direction than up. The base price includes a removable synchronous motor for 24 frames/sec, both 400- and 100-foot film chambers, and a Kodak Cine Ekton Lens, 25mm *f*/1.4. An accessory is available for any kind of time-lapse photography. Another accessory records synchronized sound. Etc., etc.

However long this recital were spun out, we doubt that the person for whom we spent 10 years making this camera is the kind who would commit himself on the strength of this ad. If he will signify his interest to Eastman Kodak Company, Motion Picture Film Department, Rochester 4, N. Y., we shall work out some arrangement to bring him, the camera, and its accessories together.

Price subject to change without notice.

How to stick together

The naive dream of a stickum to stick metal to metal without heat, waiting, clamping, or shrinkage came true in November, 1958, with the announcement of *Eastman 910* adhesive. Because it is the costliest adhesive on the market, pound for pound, we dubbed it "the adhesive to use when no other will do." This is candor gone wild. It neglects the fact that a pound yields about 14,000 drops, each of which can bond one square inch of almost anything—not just metal—to a square inch of almost anything else so that as much as 5000 pounds can be required to pull them apart. (Porous materials drink up more adhesive.)

Thousands have bought samples by mail order. Hundreds of the sample-buyers have solved serious assembly problems with the stuff. Techniques have evolved. They have to be seen to be believed. To show some of them, we have made a 15-minute sound movie for showing to professional and industrial groups. It demonstrates how-not-to's along with the how-to's.

To borrow the film for a showing, write Eastman Chemical Products, Inc., 260 Madison Avenue, New York 16, N. Y. (Subsidiary of Eastman Kodak Company).

Forced drafting

The truly creative mind tends to shy away from the petty problems of the drafting room. Then the creative mind gets angry and upset when damnable antiquated drafting procedures impede the swift and smooth transformation of its output into physical reality. Perhaps the petty problems are worth a few moments of the creative mind's time. They have solutions like

- speeding revision of drawings by picking up photographically everything from the existing drawing that is to appear in the revision
- converting drawings into rigid, dimensionally stable, non-staining, nonglaring, long-wearing overlays for contour projector screens
- making working drawings out of photographs of existing equipment instead of drawing everything
- photographic templates for standard or repeating elements in a drawing
- photographic intermediates for protecting original drawings, restoring old and worn ones, or avoiding waits for extra prints.

The Kodak Compass *is an irregular publication that will be sent free to whoever in your organization ought to be concerned with such matters. The first issue deals very plainly with pencils, inks, and eradication techniques for the new Estar Base drawing-reproduction films. Submit names to Eastman Kodak Company, Graphic Reproduction Division, Rochester 4, N. Y. Same address for quick answers to questions stirred up by these remarks.*

Kodak
TRADE MARK

This is another advertisement where Eastman Kodak Company probes at random for mutual interests and occasionally a little revenue from those whose work has something to do with science

(*Continued from p. 743*)

Canada and the United States signed an agreement last year for a cooperative effort in developing heavy-water-moderated reactors.

During 1960, the United States sold 27,335 lb of heavy water for a total of $765,380. Heavy water was also leased during 1960, to France, India, and the Republic of West Germany. AEC policy is that heavy water may be leased for use only in research, medical, or testing reactors in quantities of one short ton or more for the initial inventory requirements of the reactor. Since the first sale of heavy water in 1955, the U. S. Government has sold 988,494 lb of heavy water to foreign countries and has leased a total of 90,546 lb.

Heavy water (deuterium oxide) is separated from ordinary water in a special facility at the Savannah River plant. Heavy water contains a heavy isotope of hydrogen known as deuterium which has an atomic weight of 2, compared with ordinary hydrogen's atomic weight of 1. Water has an average of one part of heavy water to 6500 parts of ordinary water.

The advantage of using heavy water rather than light water as a reactor moderator is that fewer neutrons are lost. The neutron conservation makes possible the use of natural uranium fuels or fuels of low enrichment.

Plastic Shielding for Reactors

WHEN THE NUCLEAR SHIP *Savannah*, world's first nuclear-powered merchant ship, puts to sea, it will carry 250,000 lb of radiation protection in the form of polyethylene plate, which has been described as the most efficient neutron shield available.

The plastic plate is designed to meet the shielding needs of mobile power units where weight and space limitations are primary considerations. With its lighter weight it does the same job on water that heavier concrete does for land-based installations.

New York Shipbuilding Corp., the builder, reports the polyethylene plate was cut in various sizes and shapes to become secondary shielding around the 74-Mw pressurized water *Savannah* reactor. Depending on position, 48,530 sq ft of the plate are 1 in. thick, 1680 sq ft are $\frac{3}{4}$-in. thick, 1260 sq ft are $\frac{1}{2}$-in. thick, and 670 sq ft are $\frac{1}{4}$-in. thick. Wood and steel, in alternating layers, act as a collision pad.

The polyethylene plate on the *Savannah* has properties required by secondary neutron shield material. These include a higher hydrogen density than water, light, easy fabrication and installation, self-extinguishing and void-free characteristics, and no adverse effect on other materials with which it may come into contact. The protection material also is chemically inert to such substances as concentrated hydrochloric acid, sulphuric acid, and hydrofluoric acid.

A product of an exclusive extruding process developed by the Micarta Division of Westinghouse Electric Corp., the plate is based on Bakelite low-density polyethylene resins made by Union Carbide Plastics Co., a division of Union Carbide Corp. The Westinghouse extruding facilities are the first of their kind for the automatic, uninterrupted extrusion of thick polyethylene plate. Westinghouse reports that the chief advantage of this method lies in its high speed and freedom from voids or air bubbles. Prior to this development, polyethylene plate was produced in hydraulic presses and then X-rayed to reveal possible voids which could have reduced its effectiveness as as a shield against radiation.

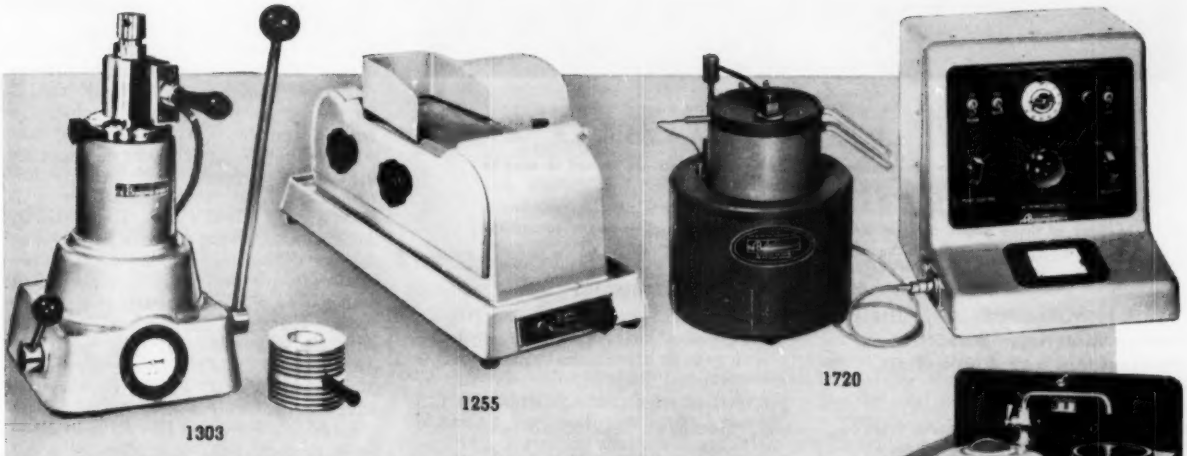
Because of its unique characteristics, the plate is finding extensive use as structural or semistructural members where its chemical inertness, thick cross-sectional stiffness, and unlimited length can be used to advantage. The plate may be fabricated with conventional woodworking tools or techniques. It can be sawed, drilled (tapping is not advised), planed, and turned. It can be nailed, bolted, clamped, or cemented into place. Mastic-type cements, epoxy adhesives, and some specially developed adhesives are being used with excellent results. The plate also may be welded or flame-sprayed.

Present capacity of the Westinghouse extrusion equipment, which produced the polyethylene plate for the *Savannah*, will turn out plate up to 48 in. wide, from $\frac{1}{2}$ to $1\frac{1}{2}$ in. thick, at any length desired (6- to 8-ft. lengths are recommended for ease of handling). The production rate is 6 million lb per year. Plans are being drawn to increase this capacity.

Good Riddance

Those bumps that annoy when you drive over the seams of a concrete highway may soon be a thing of the past, if a new mixture of concrete and fiber glass proves economically feasible. It would also reduce chances of the concrete cracking.

Arthur D. Little, Inc.



No. 1303 AB SIMPLIMET PRESS

for mounting metallurgical samples is of especially strong construction and provides unusual ease in operation. 1" and 1¼" molds are available. It accepts bakelite powder, bakelite premolds or transoptic powder.

No. 1255 AB SURFMET BELT SURFACER

offers the advantages of wet grinding on silicon carbide belts. Features include fast, accurate grinding, external coolant and centering controls, easy belt change, and access for large samples with good splash protection.

No. 1720 AB ELECTROLYTIC POLISHER

is designed for trouble free service, ease of operation and versatility in the electropolishing of metallurgical samples.

No. 1851-1 AB Polimet Polishing Apparatus

has an 8" diameter wheel with infinitely variable speed between 100 and 1200 RPM which is electrically controlled by turning a small knob. It is available also in 2 and 3 unit tables and for custom mounting.

No. 1470 AB HANDIMET GRINDER

provides the most rapid and convenient way of fine grinding metallurgical samples by hand. Four grades of adhesive backed abrasive papers are arranged side by side with coolant flowing over them for fast clean cutting.

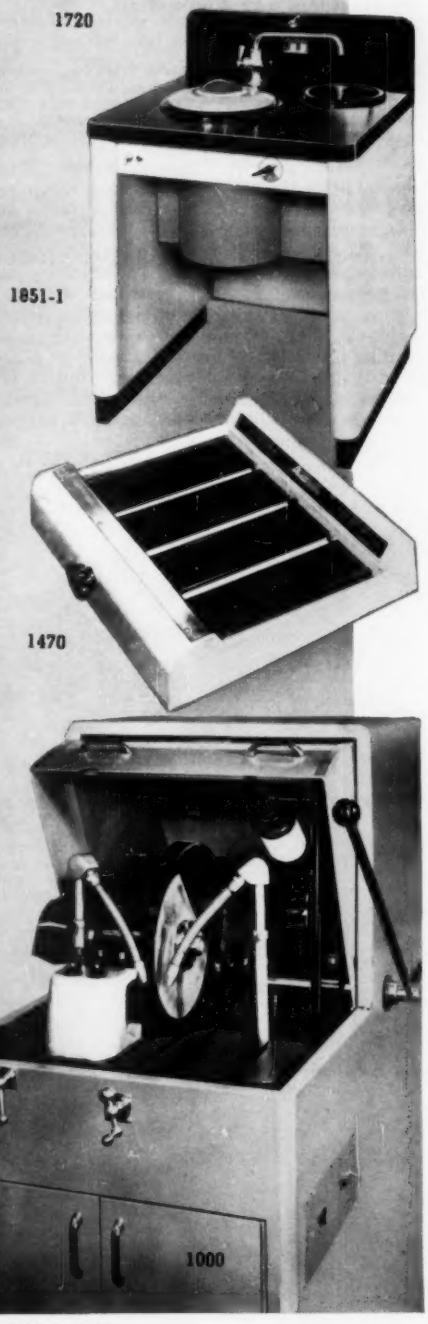
No. 1000 AB CUT-OFF MACHINE

is a heavy duty unit for abrasive cutting of metallurgical laboratory samples. It has a 5 HP motor, 12" abrasive wheel, built-in cooling system using jets or underwater cutting and a machine tool type positioning slide.

Buehler Ltd.

METALLURGICAL APPARATUS

2120 GREENWOOD ST. EVANSTON, ILLINOIS, U. S. A.



FOR FURTHER INFORMATION CIRCLE 1229 ON READER SERVICE CARD

BOOKSHELF

Members who wish to be considered for reviewing books are invited to send in their names and subjects in which they are interested. Due to customs and mailing considerations, requests from the United States only can be considered. Copies of these books are not available through ASTM; all inquiries concerning them should be addressed to the publisher.

Modern Materials: Advances in Development and Application, Vol. II.

Edited by H. H. Hausner; Academic Press Inc., New York, N. Y. (1960); 413 pp.; Illus., $12.50.

Reviewed by B. W. Gonser, Battelle Memorial Inst.

THIS IS THE second volume of a series of books "created to give the nonspecialist the benefit of obtaining information from the specialist." An avowed objective is to broaden knowledge of materials by covering the production, properties, and uses of a wide range of natural and synthetic materials. It is an ambitious program. Judging from this volume it is a worthy effort that is being capably handled.

With such a large range of subjects to cover, no effort has been made to limit each volume to related materials. Rather, this one covers in separate chapters such diverse materials as polymer-modified papers, modern flame-sprayed ceramic coatings, ceramics for cutting purposes, borides, titanium metallurgy, welding materials, and soldering materials. (The first volume covered wood, synthetic rubber, fibers, high-voltage insulation paper, special nuclear glasses, properties of ceramics, germanium, silicon, and zirconium.) The authors of these chapters are well-chosen, recognized specialists in these respective fields and they write with authority.

An excellent start on modern materials is made with "Polymer Modified Papers." This is a 61-page treatment, complete with 78 references. It covers a surprisingly broad subject, including honeycomb structures, sandwich panels, laminates, synthetic fiber papers, plastic-coated papers and the like, in an interesting, informative way. Likewise, flame-sprayed ceramic coatings are treated by Ault and Wheildon of the Norton Co. in an authoritative but very readable style which should be easily grasped by any technically trained person. Wheildon also has written the 34-page chapter on ceramics for cutting purposes. The background, properties, and applications are well covered by text and illustrations. An appendix giving six case histories of the use of ceramic cutting tools shows how very advantageous they appear in contrast to the use of carbide or other tools. However, the author does give an excellent discussion on practical considerations and the status of ceramic tool development which covers disadvantages as well as advantages.

Borides are treated in two sections—basic factors, a 47-page discussion by Professor Aronsson of the University of Uppsala, Sweden, and a shorter section on fabrication, properties, and applications by Robert Steinitz of the General Telephone & Electronics Laboratory. The section on basic factors, with nearly 200 references, presents much valuable information for the research man, not so much for the engineer with broad interests. Both sections stress that this field is very much in the development stage and that there is a vast amount of work ahead to take advantage of the unusual properties of the many borides.

(*Continued on next page*)

Titanium metallurgy, covering 100 pages and listing 165 references, is a somewhat detailed treatment of physical metallurgy only. Professors Margolin and Nielsen have excellently covered this phase of titanium from the standpoint of research metallurgists. However, for the purposes of the book a greater breadth of coverage is expected and is desirable. Thus, at least some mention of sources and extractive metallurgy of titanium is expected, as well as comments on applications, resistance to corrosion, and other factors that influence its selection in practical use. Possibly treatment of these omissions is planned for a later volume, but there is no mention of this.

Welding materials are broadly and comprehensively covered to include many of the less common metals and uncommon welding means. Under recent developments, friction welding of plastics is mentioned but not metal parts, such as pipe sections. No mention is made of hot slag welding of heavy sections as developed in Europe. These are minor compared to the vast amount of condensed information over the whole broad field.

Soft solders and soldering are briefly, but adequately, treated in the final chapter. No mention is made of silver soldering, but it is assumed that this will be covered in a later volume under brazing.

The author index is very complete and the subject index is adequate. Altogether, this is a very readable coverage of information on comparatively new materials that will be an excellent reference for those who want information beyond their own narrow specialty.

Rare Earth Elements

Edited by D. I. Ryabchikov; Office of Technical Services, No. 60-21172, U. S. Department of Commerce, Washington 25, D. C. (1960); 356 pp.; $3.75.

Reviewed by S. F. Etris, ASTM Staff.

ONE OF THE important contributions to the technical literature of the National Science Foundation in conjunction with U. S. Department of Commerce is the translation of many scientific contributions in the Russian literature. One such publication is the collective volume, "Rare Earth Metals," composed mainly of papers presented at a conference held in June, 1956, at the Institute of Geochemistry and Analytical Chemistry of the USSR Academy of Sciences. This conference reviewed all that was known about the separation, purification, and analytical determination of the rare earth elements. Certain applications of these elements in Russia were also discussed. Of interest is a statement made in one paper to the

(Continued on page 759)

MATERIALS AND TESTING TOPICS

This information is based on literature and statements from apparatus manufacturers and laboratory supply houses. The Society is not responsible for statements advanced in this publication.

FOR THE LABORATORY

Transistorized Signal—The Alinco analog sensor module, Model SAM-1, is a compact signal conditioning system of modular construction designed to accommodate low-level signal inputs from strain-gage transducers and to produce an amplified voltage proportional to the output of the transducer.
Allegany Instrument Co. **3884**

Gas Chromatography—A series of new, highly polar stationary phases for gas chromatographic analysis of steroids, sterols, terpenes, and other high-molecular-weight compounds include neopentyl glycol adipate, neopentyl glycol sebacate, neopentyl glycol adipate (terminated), and neopentyl glycol succinate.
Analytical Engineering Laboratories, Inc. **3885**

Hypot Test—A new high-potential insulation breakdown and leakage test set, the Hypot Model 4075 has been designed to meet the requirements of specification MIL-T-27A, Amendment 3, Paragraph 4.7.5, Item B. This instrument is a combination of two a-c Hypot test sets together with a phase-shift network.
Associated Research, Inc. **3886**

Strain-Gage Signal—New strain-gage signal conditioning equipment, of which the SSC-1 is the initial production model, is an 8-channel, rack-mounted unit offering any configuration of bridge circuitry (1, 2, 3, or 4 active arms); up to four calibration points; single and double shunt; plus or minus and plus and minus calibration.
Astra Technical Instrument Corp. **3887**

Digital Readout—A precise, highly versatile, portable instrument for calibration service with either tension or compression loads, designated the Type 65 automatic null balance calibration indicator, also can be used to indicate weight, force, and thrust. Digital readout in pounds eliminates any chance of reading errors which could be caused by bad parallax and incorrect interpolation of readings on instruments equipped with meters and dials.
Baldwin-Lima-Hamilton Corp. **3888**

Temperature Chambers—A series of high-low temperature chambers featuring cascade refrigeration systems use nonexplosive Freon as coolant and electric-resistance units for heating. Exteriors are constructed of mild steel, attractively finished in silver gray hammertone. Stabilized glass fiber insulation is used between outer and inner walls. Models in this "F" series are available in five test space sizes—2, 3, 8, 27, and 64 cu ft. Temperature ranges are −100 to +350 F and −100 F to +500 F.
Bemco, Inc. **3889**

Strain-Gage Plotter—A new multichannel strain-gage recording and plotting system with digital output uses 10 input conditioning modules of 10 channels each. Any module may be eliminated from a data run by a simple off-on switch. The last point is selected by a patch panel which is also used for flexowriter format control.
B & F Instruments, Inc. **3890**

Fraction Collector—A new moderately priced automatic fraction collector designed especially for gas chromatographs used in chemical and industrial research is now available. Measuring only about 1 ft. square and less than 20 in. high, the new Cenco No. 70152 automatic fraction collector can be conveniently placed on bench space next to a chromatograph to receive fractions from the chromatograph through a heated gas transfer tube. Each of six collection tubes can be automatically or semi-automatically rotated into collecting position, directed either by a panel control button or by a signal from a strip chart recorder when the indicator pen reaches a preset level.
Central Scientific Co. **3891**

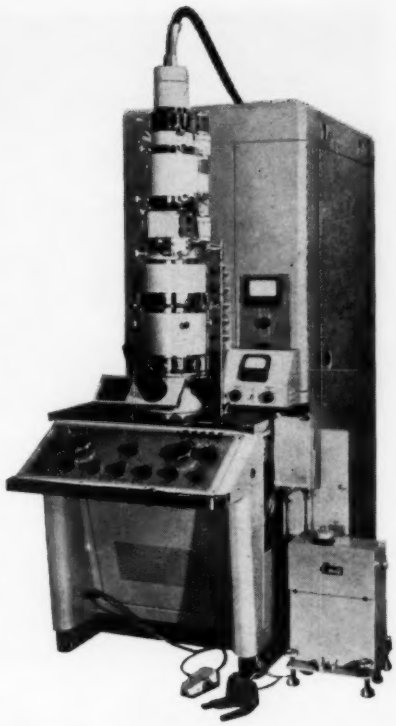
Melt Index—A new melt index apparatus measures the rate of extrusion of a thermoplastic through an orifice of a specified length and diameter under prescribed conditions. This test is described in the ASTM Method of Test for Measuring Flow Rates of Thermoplastics by Extrusion Plastometer (D 1238).
Custom Scientific Instruments, Inc. **3892**

Temperature Chamber—A new low-gradient model of quality temperature chamber, the Model 1060B chamber has temperature profile characteristics suitable for Mil. Spec. testing of large assemblies where temperature variation throughout the specimen, including gradient, control variations, and drift, is not to exceed ±1 C. The large test volume, approximately 6 cu ft, permits evaluation of fairly large specimens.
Delta Design, Inc. **3893**

Scanner—Requiring no tubes or transistors, the simple, compact, low-cost Type PE-1 photoelectric scanner system provides positive response when the light beam is interrupted by objects as small as ¼ in. wide at counting rates up to 500 per min. Depending on the light source

(*Continued on p. 755*)

HIGH-RESOLUTION, ALL-PURPOSE JEM-6A ELECTRON MICROSCOPE FROM FISHER



Now, Fisher Scientific is your exclusive United States and Canadian source for electron microscopes, related instruments manufactured by Japan Electron Optics Laboratory Co., Ltd. Model JEM-6A gives you resolving power up to 8 Angstroms for physical, chemical and metallurgical work . . . 12 A is routine. **Direct magnification:** continuously variable from 600X to 200,000X, providing photographic magnifications above 1,000,000X. **Accelerating voltages** of 50, 80 and 100 KV are extremely stable. With accessories, you heat specimens to 1000° C; cool them to −140° C; put them under tensile stress while inside the JEM-6A. A 16-mm camera films changes in crystal structure. You can record electron diffraction patterns of 1-micron fields . . . make direct-reflection photographs of surface structure. **For full details,** call your Fisher branch, or write Fisher Scientific Company, 107 Fisher Building, Pittsburgh 19, Pa.

F-195

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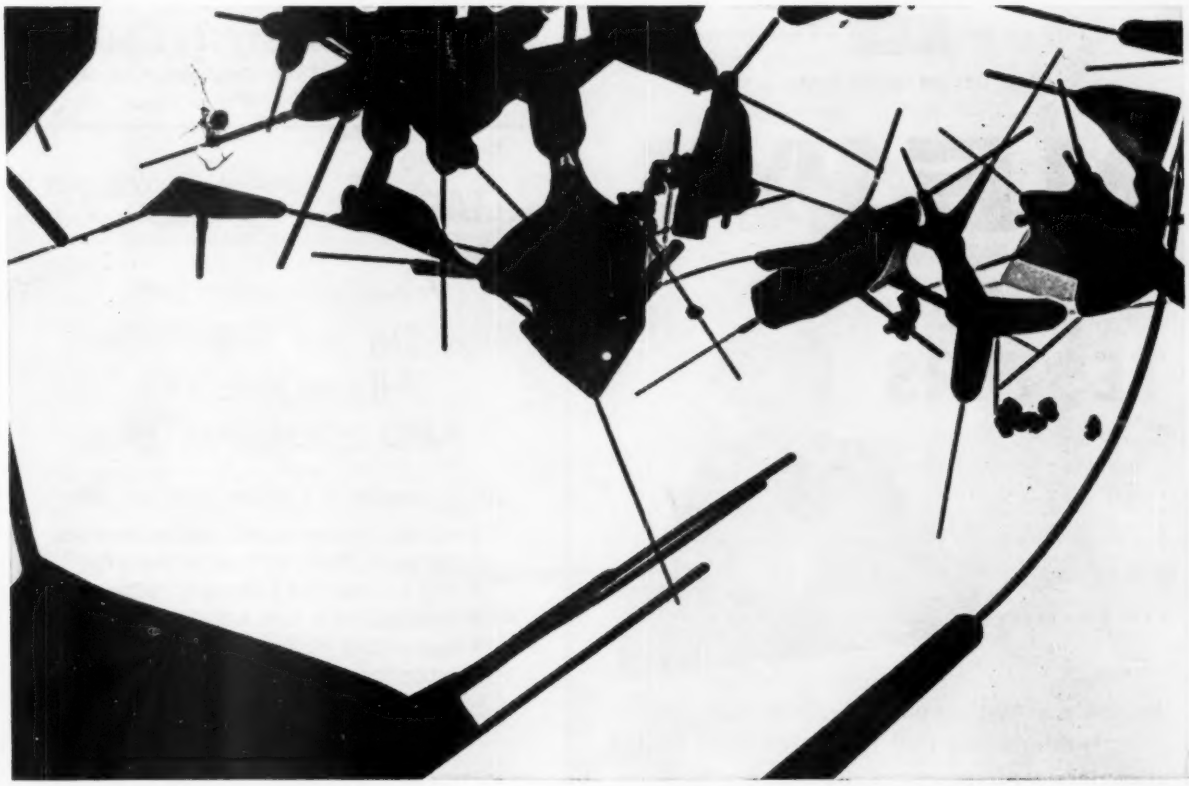

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The Eberbach Table Model Water Bath Shaker finds many applications in the fields of microbiology, biochemistry and chemistry. It provides continuous duty shaking in the range of 0 to 400 strokes per minute. The mechanical transmission assures constant speed in spite of variation in line voltage or in load.

Temperature of the bath can be controlled from ambient to 80°C plus or minus 0.5°C. Temperatures above 80°C can be obtained with an accessory auxiliary heater and gable type cover. For controlled atmosphere applications an accessory hood is available.

Immersion depth is controlled 3 ways; adjustable carrier, adaptors and water level control. Stainless steel flask carrier is 14 by 10 inches.

Model 6250 priced at..... $485.00

Request catalog 60G

P.O. Box 1024 **Eberbach** Ann Arbor, Michigan

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Pat. Pend., U.S., Canada

● Now with TENSILKUT, whatever your testing methods or materials, you can have perfect precision machined physical test specimens in less than two minutes.

● TENSILKUT precision machines all foil, film, sheet and plate metals . . . from .0005″ foil to .500″ plate. Hard .001 stainless steel foil to soft ½″ aluminum, soft plastic film 1 mil in thickness or the abrasive glass laminates in .500″ plate, are machined with specimen configurations accurate to ± .0005″. Machined edges are completely free of cold working or heat distortion and require no hand finishing.

● TENSILKUT table and floor models are available with motors from ½ to 2½ h.p. Write for free brochure.

SIEBURG INDUSTRIES INCORPORATED
Danbury Industrial Park, Danbury, Connecticut

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NEW!

PULL TESTERS

Accurate . . . fast . . . compact . . . low-cost . . . portable. Hunter's new Pull Tester offers all these advantages. Air-operated, this tester is made in 6 ranges up to 500 lbs. Write for Bulletin 750e.

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A Division of American Machine and Metals, Inc.
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MARSHALLTOWN MANUFACTURING INC.
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CIRCLE 1237 ON READER SERVICE CARD

(*Continued from p. 752*)

and photocell used, operating ranges can be up to 8 ft. Using a power-type photocell with high infrared sensitivity, and with a filter to minimize the effect of ambient visible light, this system operates a d-c relay without need for amplifiers of any kind.

Farmer Electric Products Co., Inc. **3894**

Tester—The new Forney Model LT-800, said to be the first universal testing machine designed specifically for the construction materials laboratory, is equipped for testing reinforcing bars from Nos. 2 to 11 inclusive in tension and 6 by 12 in. cylinders in compression. The standard model is a dual-range console-type machine with a maximum capacity of 250,000 lb. A heavier model, LT-900, has a capacity of 400,000 lb. Metric gages are optional.

Forney's, Inc. **3895**

Microscope—Though extremely compact, the new Reichert "Metatest" is said to be a metallurgical microscope of great versatility. For routine investigations, the Metatest is supplied with opaque illuminator facilitating bright-field and oblique illumination and an incandescent lamp for direct connection to the mains. For more critical and diversified applications, a universal opaque illuminator facilitating brightfield, dark-field, and oblique illumination and low-voltage lamp with transformer are furnished.

Wm. J. Hacker & Co., Inc. **3896**

Temperature Potentiometers—Three new, low-cost, portable potentiometers provide on-the-spot measurements of temperature for instrument maintenance departments and in testing and research work. The 8694 single-range and the 8695 double-range temperature potentiometers indicate temperatures directly in any of 15 temperature ranges.

Leeds & Northrup Co. **3897**

Pressure Testers—Pressure testers designed to operate with distilled water to avoid contamination of pressure instruments from conventional oil systems are now being manufactured. They may be used for general-purpose hydrostatic testing, comparator testing with test gages, dead-weight testing, and as dead-weight gages.

Mansfield & Green, Inc. **3898**

Fatigue Test—Complete testing apparatus for evaluating extension and compression fatigue of tire cord in accordance with the Goodyear Tube Fatigue Method is now being offered. The Scott Model GTF tester features recent design improvements developed by the Comptoir des Textiles Artificiels of France, and is based on an original design by the Goodyear Tire & Rubber Co. to conform with ASTM methods of testing tire cords (D 885).

Scott Testers, Inc. **3899**

(*Continued on p. 756*)

FOR THE LABORATORY

(*Continued from p. 755*)

Tension Recorder—A new electronic tension recorder to record tension and its changes during all preparatory operations of wires, cables, tapes, yarns, and cordage shows quickly changing tensions electrically during the preparation of wires and cables at full speed.
Tensitron, Inc. 3900

Scaler—A new and improved portable electronic scaler for use in radioactive isotope detection is light in weight, battery-operated, and transistorized with a jewelled 1-min timer accurate to 0.1 per cent of the timing cycle.
TESTlab Corp. 3901

Environmental Chamber—A new portable environmental chamber that moves to the item requiring a test, known as Model W-2-100+200, is designed for use on components, parts, and products undergoing vibration or shaker tests. A 19-in. diameter insulated dome connected to the mobile chamber with two flexible insulated hoses fits over the product.
Webber Manufacturing Co., Inc. 3902

NEW LITERATURE

Power Supply—A new bulletin describes a complete line of high-voltage d-c power supplies with outputs of 250 kv at full-load ratings of 50 ma. Described are models for general power purposes as well as facilities for test and development of capacitors, cables, klystrons and a wide range of electrical and electronic devices.
Associated Research, Inc. 6496

Disk Indicator—Detailed information on disk indicators used in measuring and control systems employing resistance strain-gage transducers is contained in *Bulletin No. 4410*. The 6-page bulletin includes specifications, connection details, diagrams showing typical system applications, and a convenient disk indicator selection chart. The SR-4 Type 12 disk indicator registers load, horsepower, torque, or pressure; requires less than a square foot of panel area for mounting, and features an exclusive, horizontal read-out window.
Baldwin-Lima-Hamilton Corp. 6497

Potentiograph—Eight-page bulletin describes the potentiograph as an automatic recording titrator for potentiometric, pH, redox, and complex titrations.
Brinkmann Instruments, Inc. 6498

Chemical Catalog—The 24-page 1961 *Chemical Order Book* for educational institutions contains an alphabetical listing of the various chemicals, reagents, solutions, biological stains, culture media, and indicators which are in the greatest demand for educational and industrial laboratories.
Central Scientific Co. 6499

Mass Spectrometer—A 6-page *Bulletin No. 21130* describes the capabilities of the Type 21–130 laboratory mass spectrometer, a cycloidal focusing mass spectrometer using a cycloid tube with 1.1-in. focal distance and a permanent magnet charged to approximately 4500 gauss. Unit resolution is attained at mass 200 with usable resolution to at least mass 230.
Consolidated Electrodynamics Corp. 6500

Potentiometer—*Fairchild Single-Turn Wirewound Potentiometers*, a 6-page illustrated brochure describing a line of linear, nonlinear, and sine-cosine precision potentiometers contains performance data on eleven models.
Fairchild Controls Corp. 6501

Sieve Shaker—An 8-page *Bulletin FS-221* describes the Fisher-Wheeler sieve shaker apparatus. Gives complete construction, use, and operating details.
Fisher Scientific Co. 6502

Laboratory Apparatus—The new 40-page *Catalog No. GS No. 161* covers laboratory supplies, apparatus, protective garments, magnetic stirrers, liquid and compressed air pumps, plastic material, and medical ware. Illustrates and describes over 300 products.
General Scientific Equipment Co. 6503

Laboratory Catalog—A complete line of scientific instruments, apparatus, and equipment has been incorporated into a new illustrated catalog available to all scientific and purchasing department personnel. Contained within its 200 plastic-bound pages are many products being shown for the first time. Included are instruments for chemical, biochemical, petrochemical, research, physical testing, and industrial control laboratories.
Labline Inc. 6504

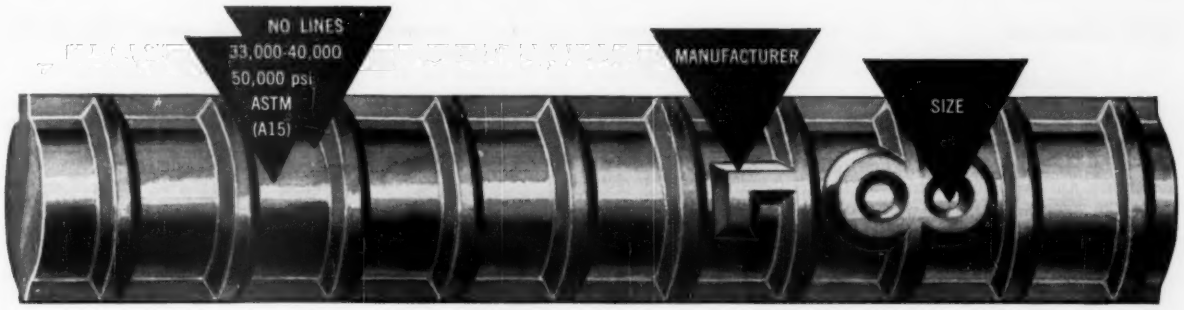
Film Badge Services—Just released is a new 8-page brochure describing radiation monitoring services. The booklet covers the complete film badge service, the different types of badges, and the evaluation of control methods used.
R. S. Landauer, Jr., & Co. 6505

Gas Chromatography—A new two-page *Data Sheet E-ND46(9)* describes Speedomax G and H recorders for laboratory gas chromatography application. The features of the Speedomax G strip-chart recorder are discussed, together with applications where a precise, flexible, and versatile instrument is required. Complete specifications are provided.
Leeds & Northrup Co. 6506

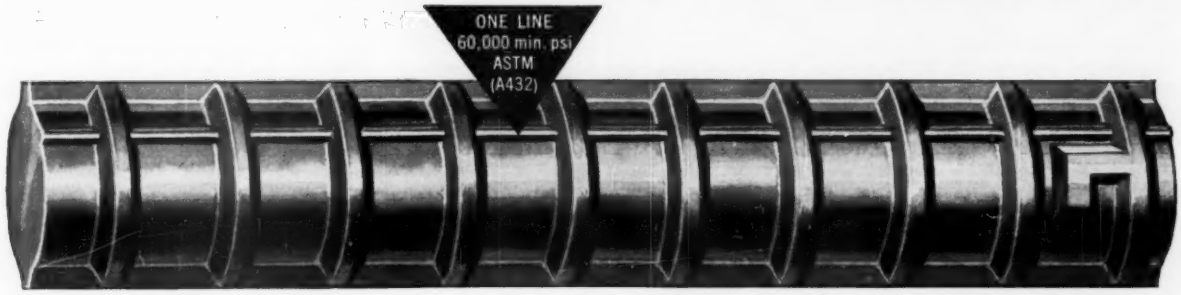
Laboratory Catalog—A new 64-page section of the *6-C Catalog*, covering steel laboratory equipment and furniture, describes and illustrates an extensive line of center, wall, auxiliary, balance, and combination tables.
Metalab Equipment Co. 6507

Radiation Counters—Two high-speed scalers for radiation counting in the clinical, industrial, and nuclear-research fields are described in *Bulletin DS*. Both are decade-type units that operate

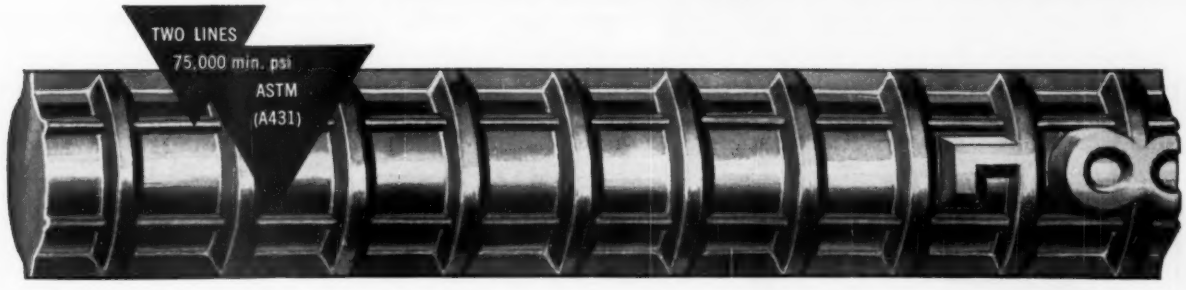
(*Continued on p. 758*)



ROLLED-IN MARKINGS



SHOW SIZE AND STRENGTH



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fast, easy identification saves construction time and cost

Metallurgical research has developed high-strength steels that substantially improve the efficiency and economy of reinforced concrete design — saving as much as 15% of the total construction cost of the structure.

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6104

FOR FURTHER INFORMATION CIRCLE 1240 ON READER SERVICE CARD

NEW LITERATURE

(*Continued from p. 756*)

with all basic nuclear detectors—proportional, Geiger-Mueller, scintillation, and neutron. An exclusive feature is their ability to signal automatically any counting error due to tube or component failure.
Nuclear Measurements Corp. 6508

Neutrons—A new 4-page folder titled "Neutrons from Small Tubes," gives design data on tubes which provide neutrons in quantities intermediate to those available from isotopic sources and reactors. Text describes main features, ion source, accelerating system, replenisher, target assembly, neutron yield, and general performance of the neutron generator tube.
Philips Electronic Instruments 6509

Titrators—Sargent *Bulletin ST* describes in detail the Sargent spectrophotometric and potentiometric titrators. These instruments are equipped for those titrations which provide potentiometric end points from the four general classes of acid base, oxidation reduction, precipitation, and complex formation. In addition, the spectrophotometric titrator includes an optical system for use in detecting end points by means of a color change in the solution.
E. H. Sargent & Co. 6510

Vibrating Screen—Complete descriptions, data and specifications, along with over 50 illustrations are presented in a new 32-page *Bulletin VS-61561*. Rotary vibrator screens, grizzly bar screens, screening feeders, mechanical conveyors screens, and pulsating magnet screens are described in detail.
Syntron Co. 6511

Laboratory Presses—A new comprehensive catalog answers questions concerning hydraulic laboratory presses from 12 to 100 ton capacity. Presses are pictured in use and construction features are presented in a diagram. Suggested applications are given.
Wabash Metal Products Co. 6512

MATERIALS

Silicone Fluids—Silicone fluids are making a significant contribution as hydraulic and damping fluids, dielectrics and lubricants, antifoam agents, coatings for ceramics and glass, and as additives in urethane foams as well as in the fields of textiles and paper release. A new, comprehensive technical reference which describes the broad range of major silicone fluids is available. The 20-page, 2-color publication differentiates between available grades of silicone fluids according to viscosity and classifies them on the basis of physical properties.
General Electric Co., Waterford, N. Y.

Urethane Insulating Foam—Dimensional stability, reduced cost, and lower density are the outstanding features of a new urethane insulating foam. A bulletin describing the material, Nopcofoam H-602, provides information on advantages, mixing, and K-factors and illustrates results of low-temperature tests on conventional foam and the new formulation. It also furnishes a listing of physical properties obtained from testing a typical panel, including densities, strengths, thermal conductivity, and dimensional stability figures. The booklet also gives a comparison of K-factors, showing the new H-602 foam as exhibiting a value of 0.13—about half that of any insulating material now in common use.
Nopco Chemical Co., North Arlington, N. J.

Reinforced Plastics—Two new reinforced plastics made with asbestos base and proprietary phenolic resins are available. The new materials are designated as Tayloron PA and Tayloron PA-6. In acetylene torch tests on $\frac{1}{4}$-in. thick panels of Tayloron PA-6, the surface of the material was brought to a temperature of more than 5000 F and required 12 to 13 min for burn-through. Temperature rise from cold face to 400 F required 200 to 210 sec.
Taylor Fibre Co., Norristown, Pa.

(*Continued from page 751*)

effect that the USSR possesses rare earth raw materials in many thousands of tons that can be obtained from the by-products of various industries, and that the USSR possesses the methods for extraction, purification, and production of these metals, but that only a few studies of the physical and chemical properties of the rare earth elements and their compounds have been made and there is no ultra-pure metal production. The Soviet author concludes that "we have made poor progress in search for fields of application of the rare earth elements and their compounds in this country, and without them the development of a rare earth elements industry will be inhibited."

Tool Steel Simplified, 3rd Edition

By F. R. Palmer and G. V. Luerssen; The Carpenter Steel Co., Reading, Pa. (1960); 608 pp; $2.50 in U.S.A., elsewhere $3.90.

Adapted from preface.

THE ORIGINAL *Tool Steel Simplified* appeared nearly a quarter-century ago. The purpose was to give tool engineers, tool makers, and tool treaters an intimate knowledge, in clear language, of tool steel. Knowledge about tool steels continues to grow in both quantity and complexity, and with it comes the necessity to continue its interpretation for those who do not have the facilities to sift out the information important to their needs. Because of this the authors presented in 1948 a revised edition of the book, and now present the second revision.

In the past few years steel-making practices and equipment have undergone considerable evolution, and Chapter 1 has been revised to cover in a broad way the current recognized practices. Chapter 6, dealing with the "Matched Set Method," has been revised to reflect the growing importance of alloy tool steels. To Chapter 7, which outlines the "Matched Set," have been added the so-called AISI numbers for convenient reference.

Chapter 10 has been extensively revised to include the important new equipment and methods of control recently made available to the hardening room, particularly those having to do with furnace atmospheres. Chapter 13, on the subject of high-speed steel, has been rewritten to fit the almost universal changeover from tungsten high-speed steels to the molybdenum types. Two new chapters have been added, one devoted to hot-worked steels and the other to air-hardening steels, both of these groups having increased greatly in importance. Chapter 20, dealing with furnace atmosphere, has been extensively rewritten to include the basic concepts of modern atmosphere control.

MATERIAL QUESTIONS

NEARLY EVERY day the mail at ASTM Headquarters includes some questions about materials, specifications, test methods, or related problems. We feel that the answers, many of which are based on information given us by officers of committees in their capacity as committee officers, are of general interest. For the most part inquiries we receive relate to the activities of the Society, either standards, research work, or publications. Often, an inquiry is such that the services of a consultant or independent testing laboratory are obviously required; in this event we do not hesitate to so recommend.

Alloys for Sealing to Glass

Do you publish a specification for alloys for sealing to glass?

● Yes, there are specifications of long standing for two such alloys—for the 17 per cent chromium-iron (F 256) and for the 28 per cent chromium-iron (F 257). A new proposed specification covering the iron-nickel-cobalt alloys for sealing to glass appears in this year's annual report preprint of Committee F-1 on Materials for Electron Tubes and Semiconductor Devices.

Water and Sediment in Crude Oils

Will you please give us some of the reasons behind the changes made in the Method of Test for Water and Sediment in Crude Oils by Centrifuge (D 96) in the 1960 revision?

● The primary reason for changing the procedure was to improve its precision. The new 8-in. cone-shape tube has a narrower tip than the old tube, thus the graduations are farther apart. The old pear-shape tube was notoriously inaccurate, primarily because it was not used under the same conditions under which it was calibrated. Consequently, it was replaced with the 6-in. cone-shape tube. While this tube is not as precise as the 8-in. tube recognized in Method D 96-60, it is included because of the wide use of small-diameter portable centrifuges in the oil fields.

Water saturation of the solvent was specified to avoid the differences in results attributable to varying water content of benzene and toluene.

The use of a demulsifier was written into the method since in actual practice very few tests gave a sharp oil-water separation. If a layer of emulsion is present, accurate readings are not possible.

The fuel oil method (D 1796) was separated from the crude oil method. Since it is strictly a laboratory method, only the more accurate 8-in. tube is recognized.

Cracking Ivory

We manufacture knives with ivory handles, and for years we have been fighting the problem of the ivory handles cracking when they dry out. I wonder if you have any information that might help us.

● Ivory is quite susceptible to changes in humidity, and we know of no way to stabilize articles made of ivory except, perhaps, to soak the finished knife handles in a 50 per cent solution of glycerine and water for quite some time, perhaps as long as a month. This may tend to stabilize them by increasing the water retention. However, you are up against the problem of a nonshrinking center (the knife tang) around which the ivory is in tension when it dries. You might avoid this circumferential tension by drying the ivory before assembly, and it would be wise to dry it from the inside by placing a dessicant (or glycerine) in the hole drilled for the tang. Cracks produced inside would seem to be unimportant or possibly help in subsequent stress conditions. Of course, dampness and expansion of the ivory after a dry assembly might loosen the bond to the tang, but this problem should be readily solvable.

(Continued on p. 762)

MATERIAL QUESTIONS

(*Continued from p. 760*)

Mica Coverslips for Tissue Cultures

We have been using microscope coverslips made of mica for tissue cultures, and owing to the peculiar results obtained with living cells, I am interested in determining some of the properties of the mica. I believe that a considerable amount of progress can be made in our research if we can determine whether our mica samples are uniform or whether there is some diversity in their structure which has influenced the variety of cellular results obtained.

● If the mica is "clear" with varying tints of pink to green when viewed on a white sheet of paper, it is probably muscovite. This, of course, can be verified by the supplier. The source of such mica can be world-wide, but the chances are it comes from India, although it might come from South America, Africa, Canada, or the United States.

If the coverslips are "clear" visual quality muscovite mica, their chemical composition and crystallographic, physical, and electrical properties would be generally the same regardless of source. While certain variations in composition do adversely affect some electrical properties of mica, it is hard to imagine how they would play any part in the anomalous behavior you are experiencing.

One possible source of variation which may be influencing your results is surface contamination, owing to the fact that mica is handled so much during the various manual operations from the crude crystal to the final part. Such contamination also degrades electrical properties, and for critical applications we clean such mica in benzene and wash it in hot distilled water. Perhaps even greater sterilization would prove beneficial in your case.

OTS REPORTS

These reports, recently made available to the public, can be obtained from the Office of Technical Services, U. S. Department of Commerce, Washington 25, D. C. Order by number.

Metals

Review of Recent Developments in the Technology of High-Strength Stainless Steels (DMIC Memo 99), *PB 161 249*, 50 cents.

Review of Current Developments in the Metallurgy of High-Strength Steels (DMIC Memo 100), *PB 161 250*, 50 cents.

OTS Selective Bibliography on Zirconium, SB-464 Zirconium (*Supplement to CTR-344*), 10 cents.

Selective Bibliography on Nickel, SB-465 Nickel, 10 cents.

Review of Recent Developments in the Technology of Molybdenum and Molybdenum-Base Alloys (DMIC Memo 96), *PB 161 246*, 50 cents.

Review of Recent Developments in the Technology of Columbium and Tantalum (DMIC Memo 97), *PB 161 247*, 50 cents.

(*Continued on next page*)

OTS REPORTS

Review of the Effects of Starting Materials on the Processes and Properties of Tungsten, Molybdenum, Columbium, and Tantalum (DMIC Memo 90), *PB 161 240*, $1.

Binary and Ternary Phase Diagrams of Columbium, Molybdenum, Tantalum, and Tungsten (DMIC Report 152), *AD 257 739*, $3.50.

Diffusion in Refractory Metals, *AD 257 860*, $3.

Electropolishing and Chemical Polishing of High-Strength, High-Temperature Metals and Alloys (DMIC Memo 98), *PB 161 248*, 50 cents.

Review of Recent Developments in the Evaluation of Special Metal Properties (DMIC Memo 94), *PB 161 244*, 50 cents.

Design Information on Titanium Alloys for Aircraft and Missiles (DMIC Report 145), *PB 151 104*, $2.25.

Statistical Summary of Mechanical-Property Data for Titanium Alloys (DMIC Memo 87), *PB 161 237*, 50 cents.

Summary of Present Information on Impact Sensitivity of Titanium When Exposed to Various Oxidizers, *PB 161 239*, 50 cents.

Investigation of the Fatigue Properties of Molybdenum under Various Conditions of Temperature, Coatings, and Stress Concentration, *PB 171 617*, $2.75.

Effect of Thermal-Mechanical Variables on the Properties of Molybdenum Alloys, *PB 171 597*, $2.50.

The Factors Influencing the Fracture Characteristics of High-Strength Steel (DMIC Report 147), *PB 151 106*, $1.25.

Application of High-Strength Aluminum Castings, *PB 171 564*, 75 cents.

Review of Current Data on the Tensile Properties of Metals at Very Low Temperatures, *PB 151 107*, $2.

Radiation Effects upon and the Recovery of the Mechanical Properties of Metals, *KAPL-2103*, $1.

Field Ion Microscopy of Iron Whiskers, *PB 171 598*, 75 cents.

Desulfurization by Calcium Inoculation Improves Properties of Cast Steel, *PB 171 384*, 75 cents.

Preliminary Observation on the Effectiveness of Heat Treatment for the Recovery of Properties of Irradiated Steels, *PB 171 188*, 50 cents.

Corrosion of Aluminum and Its Alloys in Superheated Steam, *ANL-6207*, 75 cents.

The Mechanism of Yielding and Flow in Iron, *NAA-SR-5838*, 75 cents.

Nitriding of Type 304 Stainless Steel in a Sodium-Nitrogen System, *NAA-SR-6162*, 50 cents.

Fabrication Development of UO_2-Stainless Steel Composite Fuel Plates for Core B of the Enrico Fermi Fast Breeder Reactor, *ORNL-3077*, $2.25.

Quarterly Metallurgical Progress Report No. 10, *USBM-U-819*, 75 cents.

Effect of Surface Treatment on the Corrosion Resistance of Zircoloy-2, *WAPD-TM-219*, 75 cents.

Production of Tungsten Rocket Nozzle Inserts, *Y-1343*, $1.

Corrosion of Some Reactor Materials in Dilute Phosphoric Acid, *ANL-6206*, 50 cents.

The Mechanism of Pressure Bonding, *BMI-1512*, $2.25.

Mechanical Properties of Irradiated Zirconium, Zircaloy, and Aluminum, *DP-527*, $2.25.

Summary Report on the Corrosion of Aluminum in High-Temperature Dynamic Water Systems, *HW-59778 (rev.)*, 50 cents.

Permeability of Cladding Materials to Inert Gases, *MRC-195*, 75 cents.

Design Considerations in the Use of 5000 Series Aluminum Alloys, *SCDR-243-60*, 50 cents.

Nuclear Fuels and Materials Development, *TID-11295 (Suppl.)*, $1.25.

Some Observations on the Causes and Prevention of Exaggerated Grain Growth in Zircaloy-Clad Pressure-Bonded Oxide Plate Fuel Elements, *WAPD-239*, $1.

Ceramics

Progress Relating to Civilian Applications During February 1961, *BMI-1504*, $2.50.

Progress Relating to Civilian Applications During March 1961, *BMI-1509*, $2.25.

Sodium-Graphite Interaction and Graphite Protective Coatings, *NAA-SR-6094*, 50 cents.

Ceramic Fuel Elements Made by Hot Isostatic Pressing, *SCNC-311*, $1.

Production, Precision Forming, and Sintering of Ceramic-Grade UO, *Y-1301*, $1.

The Cold Pressing of Sinterable UO_2, *Y-1340*, $1.25.

Uranium Glasses, *IS-267*, 50 cents.

Diffusion of Beryllium in Beryllium Oxide, *NAA-SR-5893*, 75 cents.

Ceramic Tubes Developed for External Heat Sources, *171 492*, $1.25.

Feasibility Study of a Glass-Coated Bead Thermister Vacuum Gauge, *SCTM 402-60(14)*, 75 cents.

(*Continued on p. 764*)

OTS REPORTS

(*Continued from p. 763*)

Radiation Tolerance of a Select Group of Semiconductor Silicon Type Diodes, *SCTM 404-60(14)*, 50 cents.

Cryogenic Engineering

A Compendium of the Properties of Materials at Low Temperature (Phase 1): Part 1—Properties of Fluids, *PB 171 618*, $6.
Part 2—Properties of Solids, *PB 171 619* $4.
Part 3—Bibliography of References (Cross-Indexed), *PB 171 620*, $3.

Polymers

Stereospecificity and Dielectric Properties of Polar Polymers, *PB 171 563*, $1.50.
Thermogravimetric Analysis of the Pyrolysis Characteristics of Polymers, *PB 171 685*, 50 cents.
Test of Plastic Fabric (Vinyl Nylon) Tarpaulins, *PB 171 525*, 50 cents.
Transparent Packaging, *PB 171 532*, $2.
Development of Ozone-Resistant Polymers with Low Hysteresis, *PB 171 578*, $2.25.
Office of Naval Research Technical Report No. 3. Part 1, Models of Stereoregular Polymers; Part 2, Stereoregularity in the Free Racial Polymerization of Vinyl Acetate; Part 3, Anionic Polymerization; Part 4, Dimensions of Polymer Chains; *PB 171 570*; $1.25.
O-Ring Materials for Naval Ordnance Applications (U), *PB 171 688*, $1.50.
Glass-Fiber Reinforced Polyester Corrugated Structural Plastics Panels, *Commerical Standard, CS 214-57*, 10 cents.
A Recommended Commerical Standard for Polyethylene Sheeting for Construction, Industrial, and Agricultural Applications, *TS-5534*, Free.
Styrene-Rubber Plastic Drain and Sewer Pipe and Fittings, Commercial Standard *CS228-61*, 10 cents.

General Testing

Symposium on Nondestructive Testing Trends in the AEC Reactor Program, *TID-7600*, $2.
Prediction of Shock Response, *SCTM 335-60 (14)*, 75 cents.
Waveform Effects in Shock Testing, *SCTM-205-60 (12)*, 75 cents.
The Dynamic Compressibility of Solids from Single Experiments Using Light Reflection Techniques, *PB 171 686*, $1.
Elastic and Plastic Stress Equations for Hollow Cylinders and Spheres Subjected to Internal and External Pressure, *PB 171 684*, $1.25.
Development of a Double Thickness/Double Density Gamma Gauge (Measures the Thickness or Density of Two Dissimilar Materials in Proximity to One Another by Gamma Photon Absorption), *NYO-2480*, 75 cents.
Radioactive Control and Regulation Methods of Industrial Processes, *AEC-tr-4139*, $4.
Shock Spectra and Design Shock Spectra, *PB 151 932*, 50 cents.

Miscellaneous

A Study of the Nature of Free Radicals in Irradiated Chemical Systems, *PB 171 596*, $1.75.
Chemical Effects of Radiation, *PB 171 572* $1.75.

NEWS OF MEMBERS

Newly elected officers at the American Wood-Preservers' Assn. include **L. J. Jacobi,** Detroit Edison Co., Detroit, Mich., president, and **D. L. Davies,** Koppers Co., Inc., Wood Preserving Div., Orrville, Ohio, first vice-president.

Fred W. Barlow, previously laboratory manager, Thermatomic Carbon Co., Division of Commercial Solvents Corp., Sterlington, La., is now supervisor, laboratory technical service, United Carbon Co., Inc., Akron, Ohio.

Ira B. Barnes, formerly chief chemical engineer, Macon Arms, Inc., Decatur, Ill., is now metallurgist, Marvil Schebler Div., Borg-Warner Corp., Decatur, Ill.

A. Allan Bates, past-president of ASTM and formerly vice-president for research and development, Portland Cement Assn., Skokie, Ill., has been named director of University Valley, New York University's new 1000-acre research and educational center, Sterling Forest, N. Y.

R. K. Bernhard, professor of engineering mechanics, Rutgers University, New Brunswick, N. J., received an honorary degree of Doctor of Engineering from the Technical University of Berlin, Germany, for his contribution "on the development of new methods for testing engineering materials and structures and as a pathfinder in the Science of Soil Dynamics."

H. G. Bimmerman, E. I. du Pont de Nemours & Co., Inc., Wilmington, Del., retired August 1, 1961. He is a long-time member of Committees D-11 on Rubber and Rubber-Like Materials and D-24 on Carbon Black. Currently Mr. Bimmerman is vice-chairman of Committee D-11 and the representative of that committee on the Council of the Materials Sciences Division and on the Coordinating Committee on Cellular Materials.

Arthur Bloomberg, prior to becoming statistician, General Instrument Co., Semiconductor Div., Hicksville, N. Y., was chief chemist, International Salt Co., Research Laboratory, New York, N. Y.

John Blumenstock, formerly a chemist with Colgate-Palmolive Co., Jersey City, N. J., is now a chemical engineer with Esso Research and Engineering Co., Linden, N. J.

Robert P. Clark has joined Nevada Testing Laboratories, Ltd., Las Vagas, Nev., as soils engineer. Formerly he was materials engineer, Capitol Engineering Corp., Saigon, Vietnam.

James R. Dillhoefer, prior to becoming chief chemist, The Flexas Corp., Chicago, Ill., was chemist, Seiberling Rubber Co., Barberton, Ohio.

(Continued on p. 766)

NEWS OF MEMBERS

(*Continued from p. 765*)

Rodolfo J. Goco, Sr., is now soils engineer, Ammann & Whitney, Teheran, Iran. Formerly he was soils technician, Morrison-Knudsen, Inc., Teheran, Iran.

L. C. Hewitt, formerly with The Ironton Fire Brick Co., Ironton, Ohio, where he was vice-president, research and development, is now director of research, Garfield Refractories Co., Bolivar, Pa.

Stanley W. Hole has accepted the position of county engineer, Lee County, Fla. He had been associated with H. J. Ross Associates, Miami, Fla.

James B. Johnson has been elected vice-president, technical director, Linear, Inc., Philadelphia, Pa. He continues in charge of research and development of O-rings and other elastomeric products.

L. E. Johnson, secretary and general manager, The Finishing Lime Association of Ohio, Toledo, Ohio, retired recently. Mr. Johnson has been a member of the Society since 1927 and has for many years been active in committee work. His committee interests include E-5 on Fire Tests of Materials and Construction, C-7 on Lime (secretary from 1956 to date), C-20 on Acoustical Materials, D-19 on Industrial Water, and ASA Project A42, Sectional Committee on Specifications for Plastering.

William F. Joseph is technical director, Rossborough Supply Co., Cleveland, Ohio. Formerly he was plant metallurgist, Precision Castings Co., Cleveland, Ohio.

C. E. Kerr, United States Air Force, Brookley AFB, Mobile, Ala., retired recently. Mr. Kerr represented the Air Force on Committees F-2 on Flexible Barrier Materials and D-10 on Packaging.

Earle W. Meckley, city engineer for the City of Allentown, Pa., retired June 30, 1961. Mr. Meckley was for 24 years a member of ASA Project A1, Sectional Committee on Specifications and Methods of Test for Hydraulic Cements.

D. M. Mortimore, formerly manager, technical control, Oregon Metallurgical Corp., Albany, Ore, is head, Analytical Laboratory, U. S. Bureau of Mines, Albany, Ore.

C. C. Mutch, Research Dept., Revere Copper and Brass, Inc., Rome, N. Y., retired August 1, 1961. Mr. Mutch, a member of the Society since 1953, represented his company on Committees B-2 on Non-ferrous Metals and Alloys, B-5 on Copper and Copper Alloys (secretary for the past year), and B-7 on Light Metals and Alloys. He had been a member of the B-5 Coordinating Committee on Non-ferrous Metals and Alloys and the Central New York District Council.

A. H. Nellen, vice-president in charge of development and research, Lee Rubber and Tire Corp., Conshohocken, Pa., retired recently. Mr. Nellen, a member of ASTM since 1924, was an active participant in the work of Committees D-11 on Rubber and Rubber-Like Materials and D-13 on Textile Materials.

I. Nimeroff, National Bureau of Standards, Washington, D. C., has been invited to do advanced study on optics and appearance properties under D. W. Wright, University of London, England. Mr. Nimeroff is a member of Committees D-1 on Paint, Varnish, Lacquer and Related Products and E-12 on Appearance.

Eliot H. Pardee is now special agent, Insurance Company of North America, Riverside, N. J. He had been manager, Research and Development Laboratory, Nassau Research and Development Co., Inc., Levittown, N. J.

W. M. Spear, formerly metallurgist, Worthington Corp., Harrison, N. J., is now foundry engineer, Mack Trucks, Inc., Plainfield, N. J.

John C. Sprague is opening a consulting practice in concrete technology, affording supplemental and auxiliary services in concrete and concreting materials. Until recently, he was associated with the Lock Joint Pipe Co. as consulting concrete engineer. In 1960, Mr. Sprague retired from the Corps of Engineers, U. S. Army, where he had served as concrete engineer and as director of the South Atlantic Division Laboratory.

Arthur W. Theuer, prior to becoming materials engineer, Charles M. Upham

Associates, Washington, D. C., was president, Foundation Constructors, Inc., Waltham, Mass.

J. A. Van den Akker, Institute of Paper Chemistry, Appleton, Wis., has been awarded a Fulbright Scholarship to teach physics at the University of Manchester, England. Dr. Van den Akker is a member of Committees D-9 on Electrical Insulating Materials and E-12 on Appearance.

Tom L. Young is now graduate assistant, Ames Laboratory, Atomic Energy Commission, Ames, Iowa. He had been research and development chemist, Atomic International, Canoga Park, Calif.

DEATHS

Karl M. Herstein, president, Herstein Laboratories, Inc., New York, N. Y. (June 1, 1961). Mr. Herstein joined the Society last year.

Frank U. Neat, assistant to superintendent of power production stations, Baltimore Gas & Electric Co., Baltimore, Md. (July 15, 1961). Mr. Neat represented his company and the Edison Electric Inst. on Committee D-19 on Industrial Water. He was taken home from the Annual Meeting and was in the hospital awaiting a gall bladder operation when he was fatally stricken with a heart attack.

NEW MEMBERS

The following 75 members were elected from July 7, 1961 to August 7, 1961 making the total membership 10,679 . . . Welcome to ASTM. Names are arranged alphabetically company members first then individuals. Your ASTM Year Book shows the areas covered by the respective Districts.

Central Plains District

Blair, E. J., supervisor, materials and processes engineering, Trans World Airlines, Inc., Kansas City, Mo.

Hartline, David A., engineer, power plant engineering, Trans World Airlines, Inc., Kansas City, Mo.

Chicago District

Brouse, Don, assistant chief of division, U. S. Forest Products Laboratory, Madison, Wis.

Johnson, Roy F., Stewart Die Casting, Division of Stewart-Warner Corp., Chicago, Ill.

Oestmann, Mary Jane, associate chemist, International Institute of Nuclear Science and Engineering, Argonne National Laboratory, Argonne, Ill.

Waddell, Joseph J., materials engineer, Soil Testing Services, Inc., Chicago, Ill.

Cleveland District

Case, E. N., metallurgical editor, Penton Publishing Co., Cleveland, Ohio.

Harper, Leslie E., chief chemist, Kolcast Industries Div., Thompson Ramo Wooldridge, Inc., Minerva, Ohio.

Jacoby, E. F., chief engineer, Engineering Dept., United States Concrete Pipe Co., Uhrichsville, Ohio.

Rode, John W., chemist, The Glidden Co., Cleveland, Ohio.

Detroit District

Long Manufacturing Div., Borg-Warner Corp., Victor A. Kortesoja, chief metallurgist, Detroit, Mich.

Michigan Testing Engineers, Inc., Raymond C. Kestner, chief of testing, Detroit, Mich.

Alder, Robert C., structural engineer, Substation Design Section, Electrical Engineering Dept., Commonwealth Associates, Inc., Jackson, Mich.

Mississippi District

American Cotton Shippers Assn., Memphis, Tenn., Ramond M. Esteve, Jr., Dallas, Tex.

Mitchell, Henry, civil engineer, Carbondale, Ill. [A]

New England District

Coates, J. J., manager, Everett Refinery, Humble Oil and Refining Co., Everett, Mass.

Cross, Grosvenor M., engineer, West Concord, Mass.

Shapiro, Herbert, senior chemist, CBS Electronics, A Division of Columbia Broadcasting System, Inc., Lowell, Mass.

Shuster, Mathew, general manager, New England Brass Co., Taunton, Mass. [A]

Van Dorn, H. B., vice-president, engineering, The Fafnir Bearing Co., New Britain, Conn.

* [A] denotes Associate Member.

(*Continued on p. 768*)

NEW MEMBERS

(*Continued from p. 767*)

Waite, Warren A., Craig Systems, Inc., Lawrence, Mass.

New York District

Petroleo Brasileiro S. A., Paulo Peres Patrocinio, chemical engineer, Refinaria Presidente Bernardes, New York, N. Y.
Gaines, Robert P., city chemist, Bayonne, N. J.
Lehr, Frank H., consulting engineer, Frank H. Lehr Associates, Newark, N. J.
Long, Esco C., standards supervisor, Lockheed Electronics Co., Plainfield, N. J.
Mausner, Marvin, director of research, Ultra Chemical Works, Inc., Paterson, N. J.
Robertson, William Donald, professor and chairman, Department of Metallurgy, Yale University, Hammond Metallurgical Laboratory, New Haven, Conn.
Rockoff, Clyde V., director, Analytical Dept., The Matheson Co., Inc., East Rutherford, N. J.
Spear, Warren M., foundry engineer, Mack Trucks, Inc., Plainfield, N. J.
Zercher, Fred W., president, Onondaga Soil Testing, Inc., Syracuse, N. Y. [A]*

Northern California District

Arden, Richard W., president, Sprout Testing Laboratory, Sparks, Nev. [A]
Fortier, Ernest C., consulting engineer, Fresno, Calif.
Munger, Milton P., Jr., supervisory materials engineer, Mare Island Naval Shipyard, Materials Laboratory, Vallejo, Calif.
Sundell, D. A., manager, quality control, General Electric Co., Oakland, Calif.
Sweet, Clyde E., Jr., highway engineer, Bureau of Public Roads, San Francisco, Calif. [A]

Northwest District

Dismore, Albert B., owner, Modern Welding Service, Great Falls, Mont.
Herbig, H. H., engineering consultant, Treasure State Industrial Products, Great Falls, Mont.
Kenworthy, Keith J., structures engineer, The Boeing Co., Seattle, Wash.

Ohio Valley District

Simmons, F. Allen, senior bridge design engineer, Bridge Dept., West Virginia State Road Commission, Charleston, W. Va.
Steinmann, W. N., vice-president, engineering, The Pollak Steel Co., Cincinnati, Ohio.
Wilson, Frank E., professor of architecture, School of Architecture, Ohio State University, Columbus, Ohio.

Philadelphia District

Sylvania Electric Products, Inc., Microwave Device Operations, John H. O'Neill, supervisor, Techniques Dept., Williamsport, Pa.
Danagher, Bernard M., Princeton Junction, N. J.
Ewing, George M., partner, G. M. Ewing Co., Philadelphia, Pa.
Glaser, Charles J., Jr., chief compounder, Research and Development Dept., Lee Rubber and Tire Corp., Conshohocken, Pa.
Heilman, Thomas N., environmental engineer, AMP, Inc., Harrisburg, Pa.
Norman, F. H., member of technical staff, RCA Laboratories, Princeton, N. J.

Southeast District

Soil Consultants, Inc., William Kenneth Johnson, president, Charleston, S. C.
Manly, William A., Jr., physicist, Physics Dept., Orr Industries Co., Division of Ampex Corp., Opelika, Ala.
Ross, H. J., owner, H. J. Ross Associates, Miami, Fla.

Southern California District

Ervin, B. H., chief engineer, Engineering Dept., Nortronics, A Division of Northrop Corp., Anaheim, Calif.
Etchason, Paul T., senior engineer, research, Autonetics, A Division of North American Aviation, Inc., Downey, Calif.

Southwest District

Franklin, B. D., instructor, Civil Engineering Dept., Agricultural and Mechanical College of Texas, College Station, Tex.
Gillespie, Thomas I., metallurgical coordinator, Continental-Emsco Co., Division of The Youngstown Steel and Tube Co., Houston, Tex.
Koons, Charles Bruce, research chemist, Jersey Production Research Co., Tulsa, Okla.
Slavin, Sidney, president, Dorsid, Houston, Tex.
Upthegrove, William R., associate professor and chairman, School of Metallurgical Engineering, University of Oklahoma, Norman, Okla.

Washington, D. C. District

DiLeonardi, Albert A., chief chemist, Kennecott Refining Corp., Baltimore, Md.
Federal Aviation Agency, S. A. Cannistra, chief, Structures Unit, Washington, D. C.
Oppenheim, Erich, production manager, Cat's Paw Rubber Co., Baltimore, Md.
Smith, Myron M., supervisory structure engineer, Design Branch, Region 3, General Services Administration, Washington, D. C.

Western New York–Ontario District

Serbu, Zaharios P., assistant engineer, Bureau of Engineering, Bridge and Structural Design, City of Rochester, Rochester, N. Y. [A]
Taylor, Carol M., seal of approval manager, Chatelaine Magazine, MacLean-Hunter Publishing Co., Toronto, Ont., Canada. [A]

Outside Established Districts

Abbott, Irving, laboratory manager, Arctic Alaska Testing Laboratories, Fairbanks, Alaska.
Bledsoe, Kenneth Wayne, geologist, Arctic Alaska Testing Laboratories, Anchorage, Alaska.

Edwards, Dale T., materials technician, Arctic Alaska Testing Laboratories, Anchorage, Alaska.

Other Than U. S. Possessions

Allawala, M. A., chief chemist, Attock Oil Co., Ltd., Rawalpindi, West Pakistan.
Cherubin, Gilbert, engineer, Societe Electrochime Ugine, Paris, Seine, France.
Coles, John, engineering assistant, Pyrotenax of Canada, Ltd., Trenton, Ont., Canada.
Forest Research Inst., Forest Products Branch, Librarian, Wakarewarewa, Rotorua, New Zealand.
Jenckel, Rudolf, manager, Atlas-Werks, Bremen, West Germany.
Ma, Seldon, Nanyang Cotton Mill, Ltd., Kun Tong, Hong Kong.
Rutherford, Vernal F., engineering assistant, Public Works Dept., Nassau, Bahamas.
Skerrett, N. P., manager, Central Laboratories Shell International Petroleum Co., Ltd., Egham, Surrey, England.
Ying, Chit-fong, member of staff, Nanyang Cotton Mill, Ltd. Kin Tong, Kowloon, Hong Kong. [A]

CALENDAR

Sept. 25–26—**Steel Founders' Society of America,** Fall Meeting, The Homestead, Hot Springs, Va.
Sept. 25–28—**American Welding Society,** National Fall Meeting, Hotel Adolphus, Dallas, Tex.
Sept. 25–28—**Association of Iron and Steel Engineers,** Convention, Penn-Sheraton Hotel, Pittsburgh, Pa.
Sept. 27–29—**American Association of Textile Chemists and Colorists,** Annual Convention, Statler-Hilton Hotel, Buffalo, N. Y.
Oct. 1–4—**American Institute of Chemical Engineers,** Lake Placid Club, Lake Placid, N. Y.
Oct. 1–4—**American Gas Association,** Annual Convention, Dallas, Tex.
Oct. 1–5—**The Electrochemical Society,** Fall Meeting, Statler-Hilton Hotel, Detroit, Mich.
Oct. 2–7—**American Rocket Society,** 12th International Astronautical Congress, Washington, D. C.
Oct. 3–5—**U. S. Atomic Energy Commission and Argonne National Laboratory,** 2nd Symposium on Physics and Nondestructive Testing, Argonne National Laboratory, Argonne, Ill.
Oct. 8–11—**National Institute of Governmental Purchasing,** 16th Annual Conference and Products Exhibit, Hotel Commodore, New York, N. Y.
Oct. 9–13—**American Association of State Highway Officials,** Annual Meeting, Statler-Hilton Hotel, Denver, Colo.
Oct. 10–14—**American Council of Independent Laboratories,** Annual Meeting, Sheraton Hotel, Philadelphia, Pa.
Oct. 15–19—**Prestressed Concrete Institute,** Annual Meeting, Brown Palace Hotel, Denver, Colo.
Oct. 15–20—**American Institute of Electrical Engineers,** Fall General Meeting, Statler-Hilton Hotel, Detroit, Mich.
Oct. 16–20—**American Society of Civil Engineers,** Annual Convention, Hotel Statler, New York, N. Y.
Oct. 19–21—**National Society of Professional Engineers,** Fall Meeting, Roanoke Hotel, Roanoke, Va.
Oct. 23–26—**The Metallurgical Society of American Institute of Mining, Metallurgical and Petroleum Engineers,** Fall Meeting, Pick-Fort-Shelby Hotel, Detroit, Mich.
Oct. 23–27—**American Society for Metals,** National Metal Congress and Exposition, Cobo Hall, Detroit, Mich.
Oct. 30–Nov. 1—**American Oil Chemists' Society,** Fall Meeting, Pick-Congress Hotel, Chicago, Ill.
Oct. 31–Nov. 4—**Federation of Societies for Paint Technology,** 39th Annual Meeting and Paint Industries' Show, Shoreham Hotel, Washington, D. C.
Nov. 1–3—**Society for Experimental Stress Analysis,** Fall Meeting International Congress on Experimental Mechanics, Hotel New Yorker, New York, N. Y.
Nov. 1–3—**Mellon Institute,** 19th Annual Pittsburgh Diffraction Conference, Mellon Institute, Pittsburgh, Pa.
Nov. 1–3—**American Concrete Institute,** 14th Regional Meeting, Dinkler-Tutwiler Hotel, Birmingham, Ala.
Nov. 6–10—**Atomic Industrial Forum and American Nuclear Society,** Annual Conference and Forum, 9th Hot Laboratories and Equipment Conference, Winter Meeting of ANS, and AtomFair Atomic Exhibit, Conrad Hilton Hotel, Chicago, Ill.
Nov. 12–15—**Air-Conditioning and Refrigeration Institute,** Annual Meeting, The Homestead, Hot Springs, Va.
Nov. 13–15—**Society of Petroleum Engineers of American Institute of Mining, Metallurgical and Petroleum Engineers, and American Petroleum Institute,** Annual Meeting, Chicago, Ill.
Nov. 13–17—**National Electrical Manufacturers Association,** Annual Meeting, Traymore Hotel, Atlantic City, N. J.
Nov. 15–18—**The Society of Naval Architects and Marine Engineers,** Annual Meeting, The Waldorf Astoria Hotel, New York, N. Y.
Nov. 26 – Dec. 1—**American Society of Mechanical Engineers,** Annual Meeting, Statler-Hilton Hotel, New York, N. Y.

GOVERNMENT STANDARDS CHANGES

THE FEDERAL Supply Service of the General Services Administration is charged with the responsibility for establishing specifications to be used by the Federal Government for Procurement of materials and supplies. The GSA issues an annual Index of Initiation of Federal Specifications Projects, and monthly supplements.

The following items appeared in Supplement 4 for June 1961.

INITIATIONS

Title	Type of Action	Symbol or Number	FSC Class	Assigned Agency & Preparing Activity
Finish of Painted Metal General Office Furniture	New	Fed. Std. 154	7110	GSA-FSS
Paint, Varnish, Lacquer, and Related Materials; Methods of Inspection Sampling and Testing.	Chg. Not. 1	Fed. Std. 141	8010	NAVY-SHIPS
Antimony Trichloride Reagent	New	O-A-565	6810	ARMY-CMLC
Cable, Power, Electrical (Rubber-Insulated, General Service) and Wire, Electrical, (Rubber-Insulated, General Service)	Rev.	J-C-103c	6145	GSA-FSS
Cable and Wire, Thermoplastic-Insulated, Building-Type (0- to 600-v Service)	Rev.	J-C-129b	6145	GSA-FSS
Cadmium Nitrate, Tetrahydrate, Analyzed Reagent	New	O-C-35	6810	ARMY-CMLC
Ethylene Glycol Monomethyl Ether Technical	New	D-E-780	6310	ARMY-CMLC
Iodine Monochloride, Reagent	New	O-I-570	6810	ARMY-CMLC
Iodine Petoyide, Analyzed Reagent	New	O-T-580	6810	ARMY-CMLC
Lithium Sulfate, Monohydrate, Analyzed Reagent	New	O-L-295	6810	ARMY-CMLC
Methyl Isobutyl Ketone	Am. 1	TT-M-268b	6810	GSA-FSS
Packing Material, Asbestos, Metallic Cloth, Sheet and Tape	Rev.	HH-P-0031c	5330	NAVY-SHIPS
Pipe, Asbestos-Cement, Underdrain, Perforated	New	SS-P-00340	5630	COM-PR
Solder, Lead Alloy, Tin Lead Alloy, and Tin Alloy; Flux Cord Ribbon and Wire, and Solid Form.	Rev.	QQ-S-571c	3439	ARMY-SIGC
Sweeping Compound	Rev.	P-S-863a	7930	ARMY-QMC
Thionyl Chloride, Reagent	New	O-T-370	6810	ARMY-CMLC

PROMULGATIONS

Title	Type of Action	Symbol or Number
Paint, Varnish, Lacquer, and Related Materials; Methods of Inspection, Sampling, and Testing	Cgh. Not. 1	Fed. Test Method Std. 141
Bolt, Square Neck; Bolt, Machine, Pinned Neck; Bolt, Tee Head; and Bolt, Key Head (Superseding FF-B-584a)	Rev.	FF-B-584b
Boxes, Fiberboard, Corrugated, Triple, Wall (Superseding PPP-B-00640a (USAF))	Rev.	PPP-B-640b
Brass, Naval (Flat Products); Plate, Bar, Sheet, and Strip (Superseding QQ-N-30)	New	QQ-B-639
Brass, Naval; Rod, Wire, Shapes, Forgings; and Flat Products with Finished Edges (Bar, Flat Wire, and Strip) (Superseding QQ-N-35)	New	QQ-B-637
Cloth, Cotton, Denim, Shrunk and Unshrunk (Superseding CCC-D-181 and CCC-D-186)	New	CCC-C-421
Cloth, Cotton, Duck, Bleached (Superseding CCC-C-442)	Rev.	CCC-C-442a
Cloth, Cotton, Duck, Unbleached, Plied-Yarns, (Army and Numbered) (Superseding CCC-C-419)	Rev.	CCC-C-419a
Cloth, Jute (or Kenaf), Burlap (Superseding CCC-C-467	Rev.	CCC-C-467a
Filler, Wood, Plastic	Am. 2	TT-F-340

SPECIFICATIONS APPROVED FOR PRINTING

Title	Type of Action	Symbol or Number
Box, Paper-Overlaid Veneer (Strap-Around Type)	Canc.	PPP-B-575
Bronze, Phosphor; Bar, Plate, Rod, Sheet, Strip, Flat Wire, and Structural and Special Shaped Sections	New	QQ-B-750
Connector, Plastic, for Flexible Tubing	New	NNN-C-550
Hose, Rubber, Preformed and Straight; Hose, Preformed, Flexible, Wire-Reinforced. (for Coolant Systems of Automotive and Other Liquid-Cooled Engines)	Rev.	ZZ-H-428b
Packing, Rubber-Sheet, Cloth-Insert	Rev.	HH-P-151e
Paint, Exterior, Chrome-Green, Ready-Mixed	Rev.	TT-P-71d
Phosphor Bronze Bars, Plates, Rods, Sheets, Strips, Flat Wire, and Structural and Special Shaped Sections	New	QQ-B-750
Pipe, Steel (Seamless and Welded) (for Ordinary Use)	New	WW-P-406b
Plastic Sheet, Extruded Acrylic	New	L-P-507
Primer Coating, Zinc Yellow, for Aluminum and Magnesium Surfaces	Am. 1	TT-P-666a
Sealer, Sanding, Lacquer Type, (for Wood Furniture)	Rev.	TT-S-190b
Slide, Microscope	New	NNN-S-450
Slides, Glass, (for Microscopy)	Canc.	GG-S-448a
Steel Castings	Rev.	QQ-S-681d
Stop Watch, Laboratory	New	GG-S-764a
Wire, Brass	Rev.	QQ-W-321c
Xylene (for Use in Organic Coatings)	Rev.	TT-X-916b

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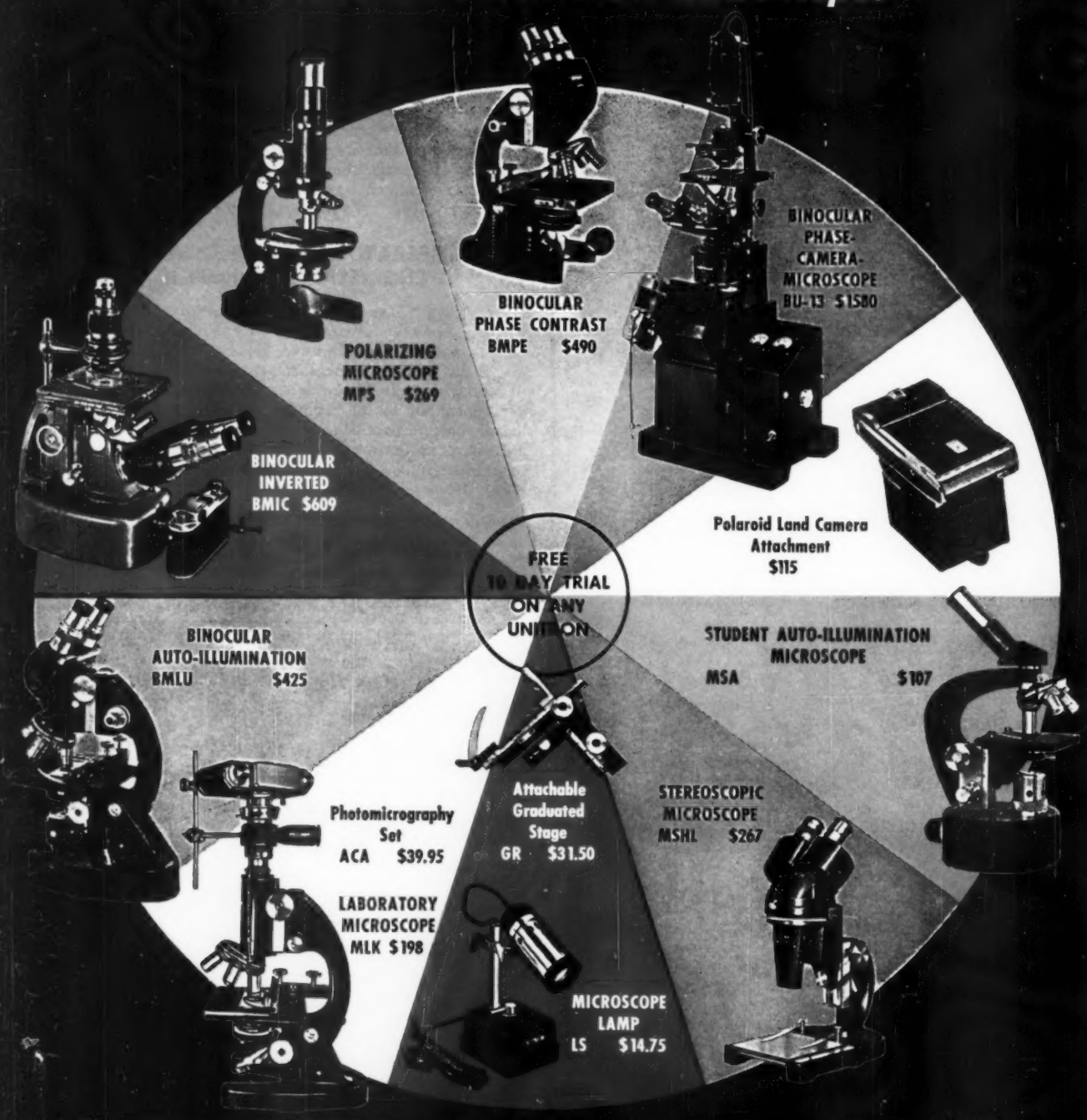

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1422-MD†, $265	0 to 1050 0 to 105	±0.03% or ±0.6pf* ±0.03% or ±0.08pf*	1422-CC, $280	5 to 110	±0.03% or ±0.15pf*
1422-ME†, $255	0 to 105 0 to 10.5	±0.03% or ±0.08pf* ±0.03% or ±0.02pf*	1422-CD, $280	0.5 to 11 0.5 to 1.1	±0.03% or ±0.04pf* ±0.03% or ±0.008pf*
1422-N, $250 (For R-F Use)	100 to 1150	±0.03% or ±0.6pf*			

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 **2 additional units** Polystyrene, $57 ± (1% + 2pf) Mica, $48 ± (0.5% + 2pf)	0.001μf total, in 0.0001μf steps	
Decade-Capacitance Boxes 1419-A Polystyrene, $205 1419-B Polystyrene, $262 1419-K Silvered Mica, $315 1419-M Paper & Molded Mica, $145	1419-A, K, M: 1.110μf total, in steps of .001μf 1419-B: 1.1110μf total in steps of .0001μf	Type 980 Decade-Capacitor Units in metal cabinet.
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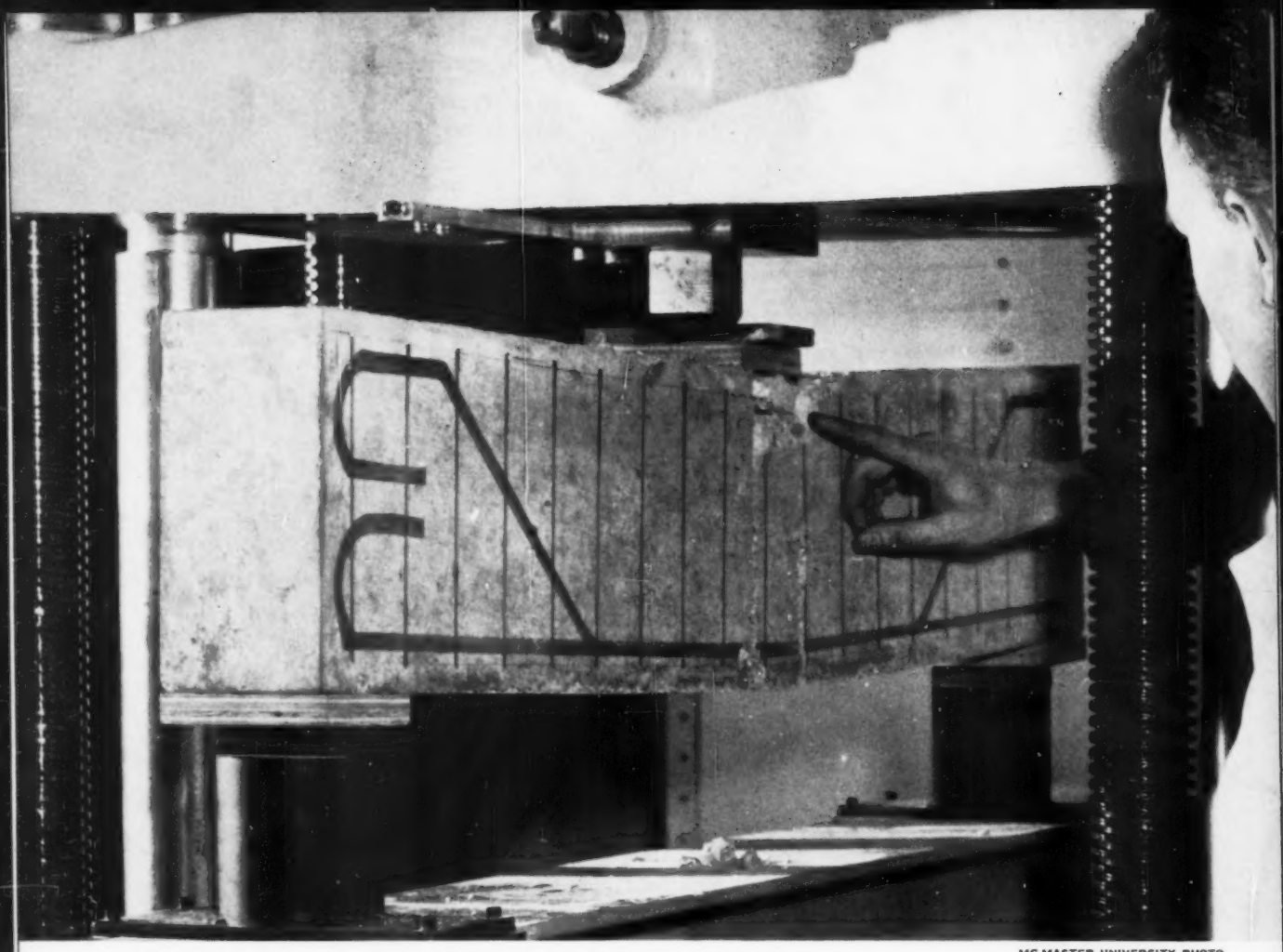

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